MODULE 27102

# Building Materials and Fasteners

SIXTH EDITION

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From *General Carpentry*

1 2022

MODULE 27102

# Building Materials and Fasteners

## Objectives

Successful completion of this module prepares you to do the following:

1. Identify safety hazards and precautions associated with wood, concrete, steel, and composite building materials.
    a. Describe the focus four and explain how to reduce hazards associated with handling carpentry materials.
    b. Explain the benefits of a job hazard analysis.
2. Identify different types of building materials and calculate needed quantities.
    a. Summarize the types of lumber, their characteristics, and how lumber is graded.
    b. Describe the types of treated lumber.
    c. Identify engineered wood products and their applications.
    d. Distinguish between the types of concrete construction materials.
    e. Describe the types of steel framing and their applications.
    f. Summarize how to calculate lumber, panel, and concrete quantities.
3. Explain how to properly handle and store building materials.
    a. Describe how to safely handle and store wood, concrete, and steel building materials.
4. Identify fasteners, anchors, and adhesives used in construction.
    a. Describe different types of nails, screws, bolts, and staples.
    b. Summarize the categories of mechanical anchors.
    c. List adhesives used in construction and identify their applications.

## Performance Tasks

Under supervision, you should be able to do the following:

1. Given a selection of building materials, identify a particular material and describe its use.
2. Calculate building material quantities using the described methods.
3. Demonstrate safe and proper installation of various types of fasteners, anchors, and adhesives.

**CODE NOTE**

Codes vary among jurisdictions. Because of the variations in code, consult the applicable code whenever regulations are in question. Referring to an incorrect set of codes can cause as much trouble as failing to reference codes altogether. Obtain, review, and familiarize yourself with your local adopted code.

**VIDEOS for Module 27102: Building Materials and Fasteners**

*Scan this code using the camera on your phone or mobile device to view the videos related to this module.*

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## Overview

Carpenters use a wide variety of materials to work in practically every phase of construction. Whether their focus is residential, commercial, industrial, or infrastructure, carpenters work with a variety of materials including wood, concrete, steel, and composites. Along with using a variety of materials, carpenters generally are classified as either a rough or finish carpenter. This module reviews the types of materials used by carpenters, associated hazards and precautions, and related construction fasteners and adhesives.

### Industry Recognized Credentials

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# 1.0.0 Safety Precautions with Building Materials

### Objective

Identify safety hazards and precautions associated with wood, concrete, steel, and composite building materials.

a. Describe the focus four and explain how to reduce hazards associated with handling carpentry materials.
b. Explain the benefits of a job hazard analysis.

### Performance Tasks

There are no performance tasks in this section.

When you accept a job as a carpenter, you have a safety obligation to your employer, coworkers, family, and yourself. In exchange for your wages and benefits, you agree to work safely. You are also obligated to make sure anyone you work with is working safely. Likewise, your employer is obligated to maintain a safe workplace for all employees. The ultimate responsibility for on-the-job safety, however, rests with you. Whether installing a window unit or unloading and storing building materials and supplies, safety is *your* responsibility.

## 1.1.0 Carpentry Safety

**Focus four**: The four leading causes of death in construction work: falls, struck-by hazards, caught-in or caught-between hazards, and electrical hazards.

The four leading causes of death in construction work are called the **focus four**. The focus four—also known as the *fatal four*—are responsible for almost 60% of the construction industry's fatalities. The focus four includes falls, struck-by hazards, caught-in or caught-between hazards, and electrical hazards. As shown in *Figure 1*, the number of deaths from falling exceed the number caused by the other three hazards. Always be alert to job conditions that place you or your coworkers in any of these potentially deadly situations.

Explanations of the four leading hazard groups are as follows:

- Falls from elevation are incidents involving failure to provide, or failure to use appropriate fall protection.
- Struck-by accidents involve unsafe operation of equipment, machinery, and vehicles, as well as improper handling of materials, such as through unsafe rigging operations.
- Caught-in or caught-between accidents involve unsafe operation of equipment, machinery, and vehicles, as well as improper safety procedures at a **trench** site or other **confined space**.
- Electrical shock accidents involve contact with overhead wires, use of defective tools, failure to disconnect power source before repairs, or improper **ground fault** protection.

**Trench**: A narrow excavation made below the surface of the ground that is generally deeper than it is wide, with a maximum width of 15 feet (4.6m).

**Confined space**: A work area large enough for a person to work in, but with limited means of entry and exit and not designed for continuous occupancy. Tanks, vessels, silos, pits, vaults, and hoppers are examples of confined spaces.

**Ground fault**: Incidental grounding of a conducting electrical wire.

### 1.1.1 Personal Protective Equipment

All carpenters are responsible for wearing the appropriate personal protective equipment (PPE) while on the job. When worn correctly, PPE is designed to protect you from injury. It is important to keep PPE in good condition and to know when PPE should be used for a given task. Many workers are injured on the job because they are not using proper PPE. Not all potentially dangerous conditions can be seen just by looking around a jobsite. Stop and consider what type of accidents could occur for any task you are about to perform. Using common sense and knowing how to use PPE greatly reduces your risk of injury, regardless of what construction material is used.

### 1.1.2 Good Jobsite Housekeeping

While the bulk of building materials on a construction project are put to use, a certain amount of scrap and other debris are produced during typical

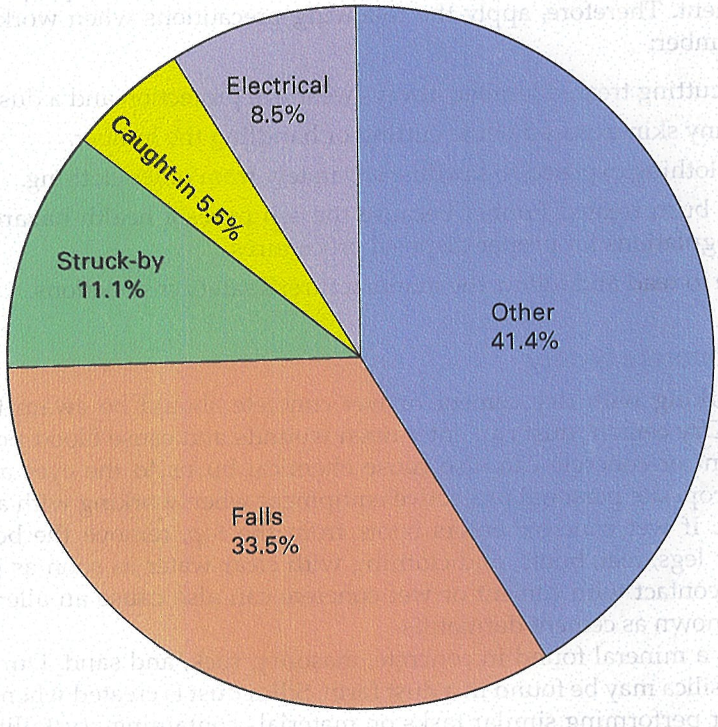


**Figure 1** Construction's four leading hazards.
*Source:* US OSHA, 2018

construction processes. Good jobsite housekeeping is required to help prevent accidents. Good housekeeping rules include the following:

- Remove all scrap material from the work area.
- Clean up spills.
- Remove all **combustible** scrap materials regularly.
- Make sure there are containers for the collection and separation of refuse. Containers for flammable or harmful refuse must have a lid.
- Store all tools and equipment when you are finished using them.

**Combustible**: Capable of easily igniting and rapidly burning; used to describe a fuel with a flash point at or above 100°F.

Depending on the size of the construction project, many types of building materials are delivered to the jobsite in bulk (large quantities). Always use appropriate material-handling equipment when lifting and/or handling heavy objects or large quantities of building materials. When lifting heavy materials, bend your knees, hold the load closely, and keep your back straight while standing up. Many construction injuries can be attributed to improper lifting techniques.

### 1.1.3 Wood Product Safety

One of the most common injuries associated with wood products is embedded splinters. Many of these injuries can be avoided if the proper gloves are worn when handling building materials. Along with preventing embedded splinters, gloves help to prevent cuts or scrapes when handling sharp objects. Never wear gloves around rotating or moving equipment as they can easily get caught up in the equipment.

When stacking materials, such as lumber, ensure they are secure to prevent them from falling or sliding. For lumber, place the pieces flat on the ground, and do not stand them on end. Depending on the area where the lumber is stored, scrap lumber or short 2 × 4s may be placed under the lumber at a 90-degree angle to prevent the lumber from contacting the ground. Do not pile lumber more than 6' high if moving it manually.

Chemicals used in treated lumber may present a hazard to people and the environment. Therefore, apply the following precautions when working with treated lumber:

- When cutting treated lumber, always wear eye protection and a dust mask.
- Wash any skin exposed while cutting or handling the lumber.
- Wash clothing exposed to sawdust separately from other clothing.
- Do not burn treated lumber because the ash poses a health hazard. Check local regulations for proper disposal procedures.
- Be sure to read and follow the manufacturer's safety instructions.

**Plywood Safety**

Plywood is awkward to carry. Remember, carry only one sheet of plywood at a time, and do not hold it over your head. In strong winds, use caution as the plywood could act like a sail and injure you and others on the jobsite.

### 1.1.4 Concrete Safety

Those working with dry cement or wet concrete should be aware that it is harmful. Dry cement dust can enter open wounds and cause blood poisoning. Wet cement or concrete can also cause chemical burns to the eyes and skin. Wear appropriate personal protective equipment when working with any form of cement. If wet concrete enters boots from the top, remove the boots and rinse your legs, feet, boots, and clothing with clear water as soon as possible. Repeated contact with cement or wet concrete can also cause an allergic skin reaction known as cement dermatitis.

Silica is a mineral found in concrete, masonry, rock, and sand. During construction, silica may be found in a dust form. Silica dust is created when cutting, drilling, or performing similar tasks on materials containing crystalline silica. Prolonged exposure to silica dust can cause **silicosis**, which is an incurable, and sometimes fatal, lung disease. The time it takes for silicosis to develop varies based on the length of time and the amount of silica exposure. In addition to silicosis, the inhalation of silica dust increases the risk of lung cancer and **chronic obstructive pulmonary disease (COPD)**. Individuals working closely

**Silicosis**: A serious lung disease resulting from the inhalation of crystalline silica particles.

**Chronic obstructive pulmonary disease (COPD)**: Lung diseases that result in the obstruction of lung airflow and interfere with normal breathing. Chronic bronchitis and emphysema generally fall under the diagnosis of COPD.

with materials containing silica, such as workers operating abrasive blasting (sandblasting) equipment, also risk the development of kidney disease.

**WARNING!**

When working in an area where silica dust is present, use the appropriate respiratory protection. Never work around silica dust without proper training, authorization, and PPE.

OSHA holds employers responsible for protecting workers from crystalline silica. *29 CFR, Part 1926.1153,* known in the workplace as the *silica standard,* outlines the steps for controlling exposure when working with sand, stone, concrete, and similar materials. Options are available for keeping workers safe, as well as methods to monitor exposure.

The basic requirements for employers include the establishment and implementation of a written silica exposure control plan that identifies tasks leading to exposure and the approaches to protecting workers. In addition, employers must do the following:

- Designate a competent person to ensure the exposure control plan is effectively implemented.
- Establish procedures to restrict access to areas where silica dust is actively generated.
- Train workers on tasks that create silica dust and ways to limit exposure.
- Limit common housekeeping practices that expose workers to silica dust when an alternative is available.
- Provide medical exams that include lung-function tests and x-rays every three years for workers who wear a respirator for 30 or more days each year.
- Keep records of all the above.

The primary means of management is to use saws and similar power tools equipped with a built-in water-delivery system (*Figure 2*). Water prevents the

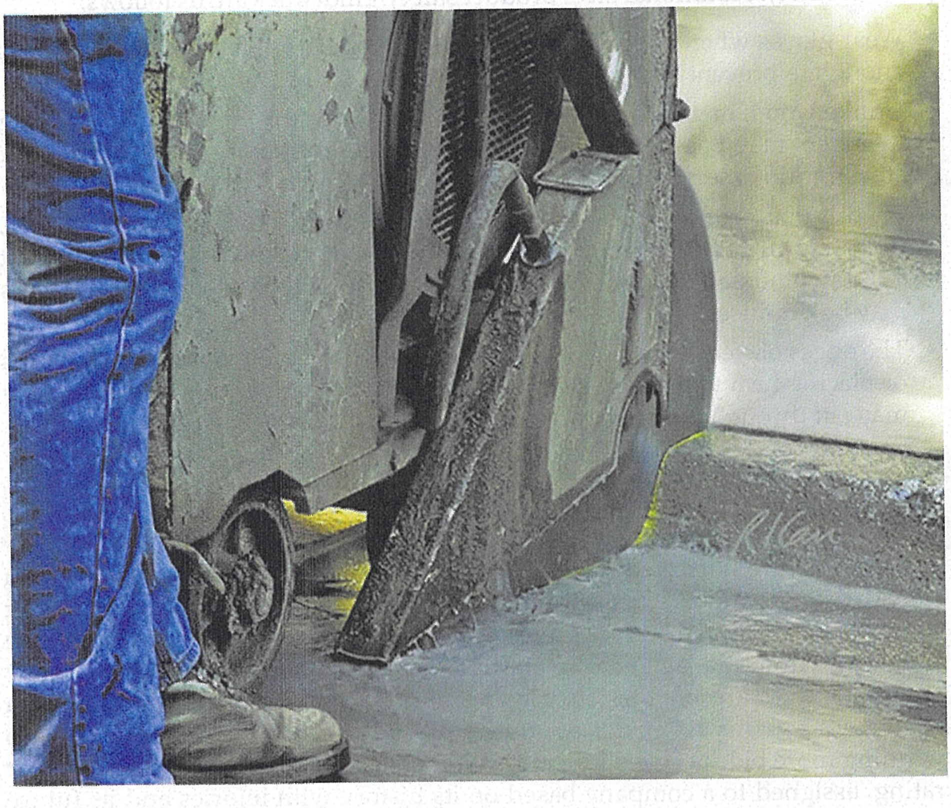


**Figure 2** Concrete saw with water-delivery system.
*Source:* Robert I. Carr, Ph. D., P.E.

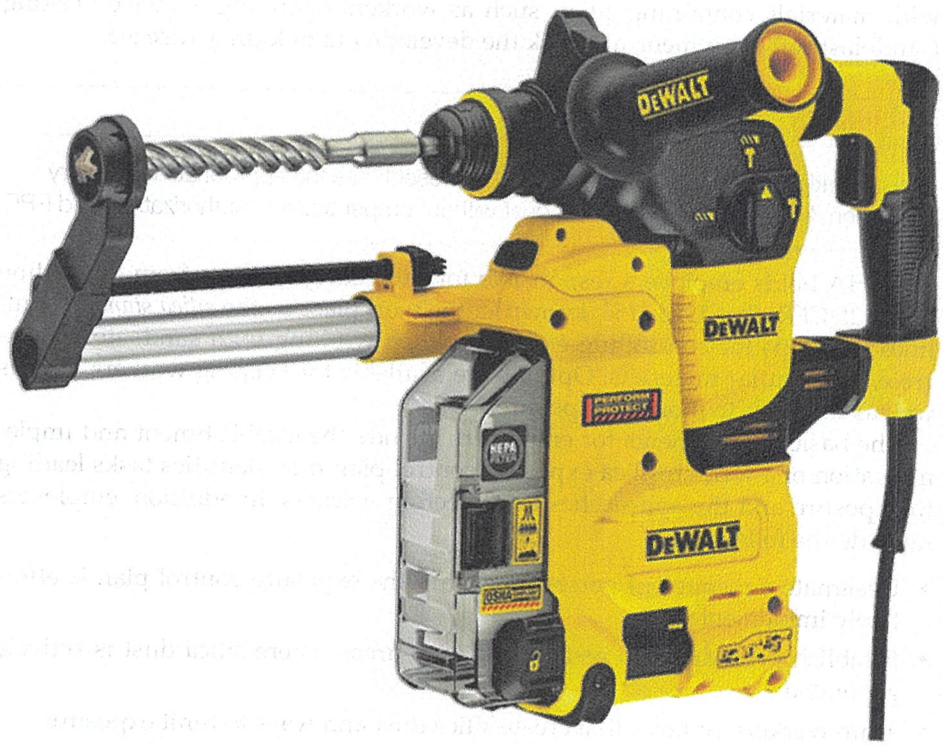


**Figure 3** Rotary hammer drill with on-board dust extractor.
*Source:* Image property of Stanley Black & Decker. Used with permission.

dust from becoming airborne. Handheld and stand-mounted concrete drills must have a dust collection system connected to a vacuum (*Figure 3*).

### 1.1.5 Steel Product Safety

Many of the general safety guidelines previously discussed also apply to steel product safety. Additional steel product safety guidelines are as follows:

- Wear gloves when handling steel framing members. Gloves should be thick enough to prevent penetration by sharp edges of the framing members.
- Unlike wood, metal does not absorb moisture. For this reason, steel framing members may become slippery when wet. Use caution when handling wet steel framing members.
- Ensure that proper PPE is used, including hearing protection and goggles, when cutting steel framing members with a cutoff saw. When metal is cut with a cutoff saw, a loud noise may be emitted and flying metal fragments may be produced.
- The edges of steel framing members may be sharp. Avoid dropping members or placing heavy loads of steel framing members on electrical cords as they may cut through the cord and create an electrical hazard.

**CAUTION**

Some steel framing members are galvanized with a zinc coating to prevent corrosion. When zinc reaches an elevated temperature (over 900°F)—such as when welding or cutting framing members—the zinc burns and emits a zinc oxide vapor that can irritate the lungs and may lead to difficulty breathing. Craftworkers exposed to high concentrations of zinc oxide over prolonged periods of time can develop a condition known as the zinc chills, which can produce fevers and tremors.

## 1.2.0 Creating a Safety Culture

A safety culture is created when a company sees and embraces the value of a safe work environment. Creating and maintaining a safety culture is an ongoing process that includes sound safety practices and training. Everyone in the company—from management to craftworkers—must be responsible for safety whenever they are on the job. Having a strong safety culture can lower a company's **experience modification rate (EMR)**, which can lead a company to winning more bids and keeping more workers employed. EMR is a number, or rating, assigned to a company based on its history with injuries and its future risks of experiencing more loss. Insurance companies often use this rating to price workers' compensation premiums.

**Experience modification rate (EMR)**: A rating used to determine surcharge or credit to workers' compensation premiums based on a company's accident experience and potential for future losses.

## 1.2.1 Job Hazard Analysis

Before starting each day, consider the hazards you might encounter and take corrective action to minimize your risk of injury. One way to promote safety in your workplace is to conduct a daily **job hazard analysis (JHA)** at the start of each workday. A **hazard** is something that may be present on the jobsite that can cause immediate harm. The JHA is a technique used to assess existing and potential jobsite hazards, understand related risks before they occur, and determine how the risks can be eliminated or controlled. In addition to helping to create a safety culture, the Occupational Safety and Health Administration (OSHA) strongly encourages the use of JHAs on the worksite. Performing regular JHAs has several key benefits:

**Job hazard analysis (JHA)**: An approach that emphasizes job tasks to identify hazards before they cause any harm. The focus is on the relationship between the worker, the task, the tools, and the work environment.

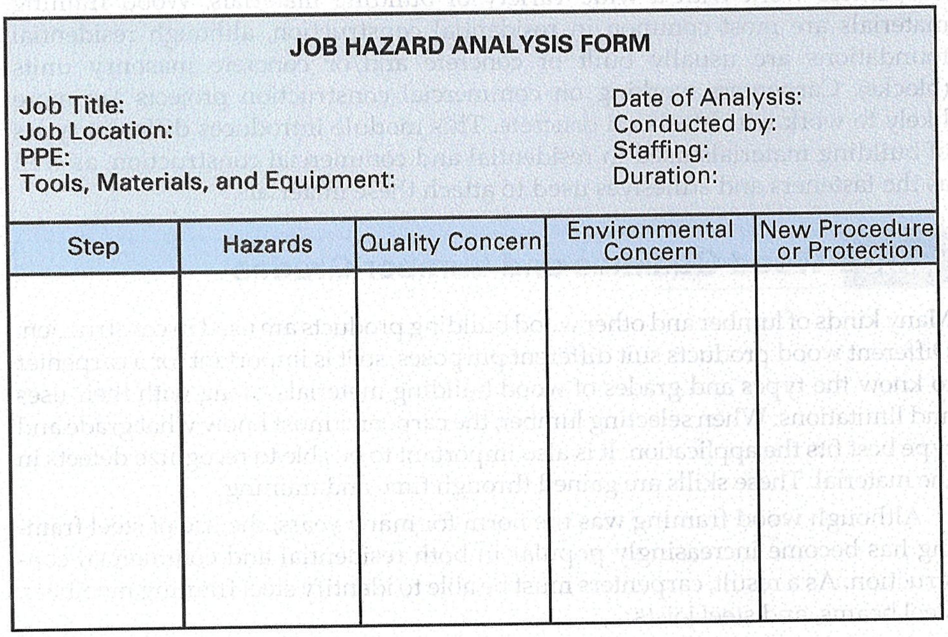
**Hazard**: Something that may be present on the jobsite that can cause immediate harm.

- *Recognition of hazardous conditions*—As one of the primary goals and benefits of JHAs, reducing the number of workplace hazards is good for you and your employer. Following OSHA standards is important, and identifying potentially hazardous tasks is an extra benefit of the JHA.
- *Better communication*—JHAs may require input from employees and supervisors working on a project in different areas. The result is increased communication and more opportunity to discover potential safety hazards.
- *Job safety standards compliance*—Along with providing a safer workplace, performing JHAs helps ensure compliance with OSHA standards and provides greater protection from potential legal and financial penalties.
- *Consistency of routines*—JHAs break down each job into steps reviewed by workers. Doing so ensures the routines are fully reviewed and applied consistently on the jobsite.

When performing a JHA, tasks are broken down into their individual steps and then are analyzed for potential hazards. If a hazard is identified, certain actions or procedures are recommended to correct or prevent it. *Figure 4* shows an example of a form used to conduct a JHA.

JHAs can also be used as pre-planning tools, which helps ensure that safety is planned into the job. As a carpenter on a jobsite, you may be asked to take part in a JHA during job planning. When JHAs are used as pre-planning tools, they typically review the following information:

- Tools, materials, and equipment needs
- Staffing or manpower requirements
- Duration of the job
- Quality concerns



**JOB HAZARD ANALYSIS FORM**

Job Title:
Job Location:
PPE:
Tools, Materials, and Equipment:

Date of Analysis:
Conducted by:
Staffing:
Duration:

| Step | Hazards | Quality Concern | Environmental Concern | New Procedure or Protection |
|---|---|---|---|---|
| | | | | |

**Figure 4** Job hazard analysis form.

## 1.0.0 Section Review

1. What is the deadliest construction job hazard?
   a. Falling
   b. Getting caught between objects
   c. Electrocution
   d. Getting struck by objects

2. When used with a concrete saw, what can reduce the amount of airborne silica dust?
   a. Carbon black
   b. Negatively charged blades
   c. Water
   d. Blowers

3. Something on the jobsite that may result in an injury or illness is referred to as a(n) _____.
   a. experience modification rate
   b. hazard
   c. accident
   d. job hazard analysis

## 2.0.0 Building Materials and Their Uses

### Performance Tasks

1. Given a selection of building materials, identify a particular material and state its use.
2. Calculate building material quantities using the described methods.

### Objective

Identify different types of building materials and calculate needed quantities.

a. Summarize the types of lumber, their characteristics, and how lumber is graded.
b. Describe the types of treated lumber.
c. Identify engineered wood products and their applications.
d. Distinguish between the different types of concrete construction materials.
e. Describe the types of steel framing and their applications.
f. Summarize how to calculate lumber, panel, and concrete quantities.

Carpenters work with a wide variety of building materials. Wood framing materials are most common in residential construction, although residential foundations are usually built of concrete and/or concrete masonry units (blocks). Carpenters working on commercial construction projects are more likely to work with steel and concrete. This module introduces different types of building materials used in residential and commercial construction, as well as the fasteners and adhesives used to attach these materials.

## 2.1.0 Wood Qualities and Lumber Grades

Many kinds of lumber and other wood building products are used in construction. Different wood products suit different purposes, so it is important for a carpenter to know the types and grades of wood building materials, along with their uses and limitations. When selecting lumber, the carpenter must know what grade and type best fits the application. It is also important to be able to recognize defects in the material. These skills are gained through time and training.

Although wood framing was the norm for many years, the use of steel framing has become increasingly popular in both residential and commercial construction. As a result, carpenters must be able to identify steel framing members, steel beams, and steel joists.

### Building a New House

If wood is used for a new house, expect to see a lot of it on the jobsite. Approximately 14,000 board feet of lumber is used to build an average-size house.

## 2.1.1 Hardwoods and Softwoods

Throughout the ages, people have used wood for a variety of purposes: as fuel, as building materials, for weapons, and in transportation. In this module, it is important to distinguish lumber from wood. Lumber refers to the boards, timbers, and other products produced at sawmills. Wood refers to the material itself, which comes from many species of trees.

The use of wood in construction has several advantages:

- It is easily worked.
- It has durability and beauty.
- It has great ability to absorb shocks from sudden loads.
- It is free from rust and corrosion, comparatively light in weight, and adaptable to a countless variety of purposes.

Lumber, as well as the trees it comes from, are classified as either hardwood or softwood. This classification can be somewhat confusing as some softwoods are actually harder than hardwoods, and certain hardwoods are softer than some softwoods. The general distinction is made that softwood trees have needles, are coniferous (cone bearing), and retain their green needles throughout the year. Pine and fir trees are two types of softwood trees. Hardwoods come from deciduous (leaf-bearing) trees, such as oak and maple, which lose their leaves each fall. Descriptions and uses of various hardwoods and softwoods are provided in *Appendix B*.

Wood is useful as a building material because of the way a tree forms its fibers: growing by the addition of new material to the outer layer just under the bark and preserving its old fibers as it adds new ones.

Viewing a cross section of a tree, as shown in *Figure 5*, one can see that the trunk consists of a series of concentric rings covered by a layer of bark. Each annular ring represents one year of tree growth. This growth takes place just under the bark in the cambium layer.

As one layer of wood succeeds another, the cells in the inner layer die (cease to function as food storage) and become useful only to give stiffness to the tree. This older wood, known as heartwood, is usually darker in color, drier, and harder than the living layer (sapwood). Heartwood is more durable than sapwood. If wood is to be exposed to decay-producing conditions without the benefit of a preservative, a minimum percentage of heartwood will be specified. Sapwood takes preservative treatment more readily than heartwood, and it is equally durable when treated.

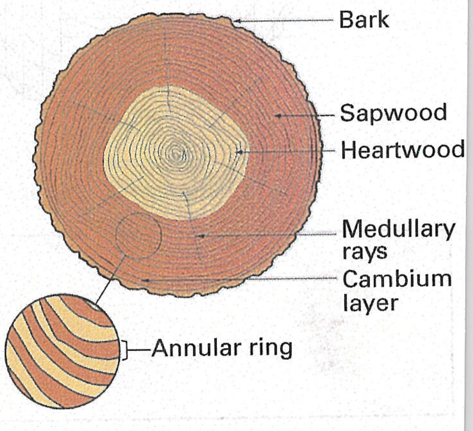


**Figure 5** Cross section of a tree.

FIED HARDWOOD
l products come from well managed forests,
d in accordance with the rules of the Forest
Certified by Scientific Certification Systems
VHITE MAPLE
ED COLLINS
)ARD CORE
STRIES INC.
!753
FSC
FSC Trademark® 1996 Forest Stewardship

### Going Green

**Certified Wood**

Look for sustainably harvested materials when constructing. Several organizations evaluate wood products to determine if they are sustainably harvested. One organization is the Sustainable Forestry Initiative (SFI), which maintains a system of principles and objectives focused on perpetually growing and harvesting trees while protecting wildlife, soil, plants, and water quality. The SFI program was created in 1994 to safeguard North America's forests and to ensure others in the forest products industry adhered to sustainable forestry practices. More information on SFI is available at **https://www.forests.org/**. Another organization is the Forest Stewardship Council (FSC). The FSC's wood certification standards are available at **https://us.fsc.org/**.

## 2.1.2 Types of Lumber Cuts

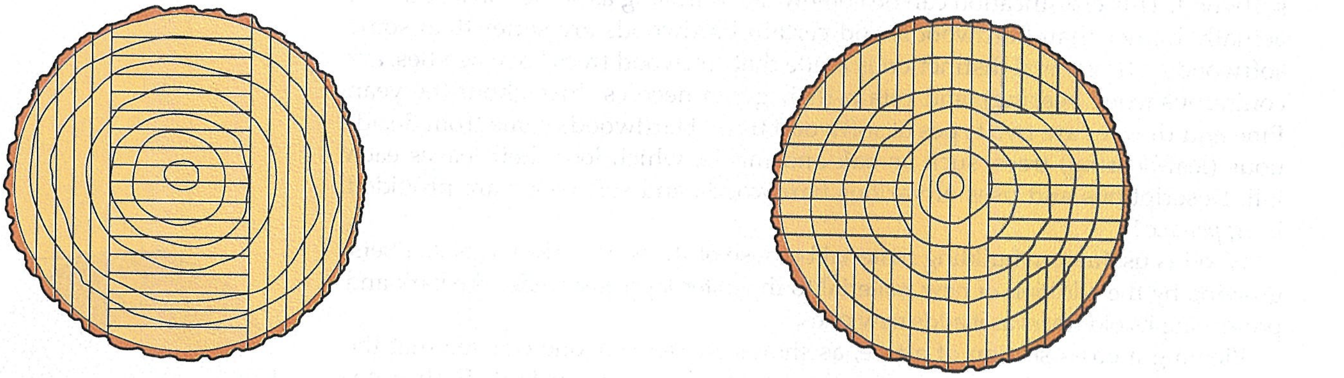
Most trees are sawed so that the annular rings form an angle of less than 45 degrees with the surface of the boards. This type of lumber is called flat-grained in softwoods and plain-sawn in hardwoods (*Figure 6*). This is the least expensive method and minimizes waste, but the lumber produced by this method is more likely to shrink or warp.

In another sawing method, the wood is cut with the annular rings at an angle greater than 45 degrees with the surface of the boards. Lumber cut by this method is known as edge-grained or vertical-grained in softwoods and quarter-sawn in hardwoods. The lumber produced by this method is usually more durable and less likely to warp or shrink. Quarter-sawn lumber is often used for hardwood floors.

To obtain the maximum amount of lumber from a log, most logs are cut using a combination of these two methods.

## 2.1.3 Lumber Characteristics and Defects

Lumber grading is based on the number and types of defects in the lumber, so knowledge of lumber grading requires understanding the characteristics of wood. Some lumber characteristics, such as knots, occur naturally. Damaged lumber can be the result of improper storage and handling or the cutting and planing process. Some defects can occur while the lumber is drying. Lumber defects can affect the lumber's appearance, strength, and usability. For most



Plain-sawn
(flat-grained) lumber

Quarter-sawn
(edge-grained) lumber

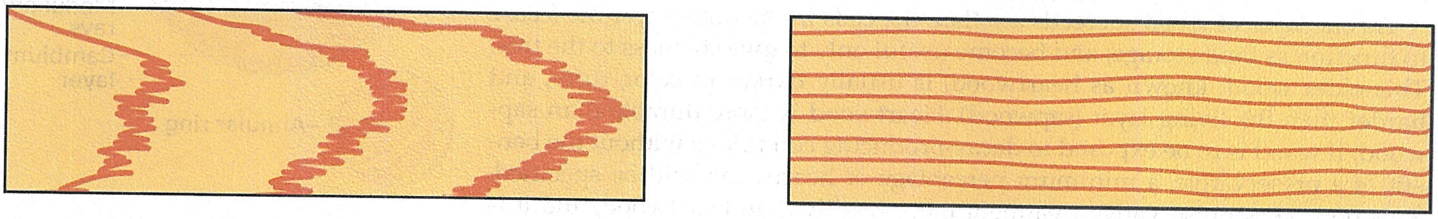
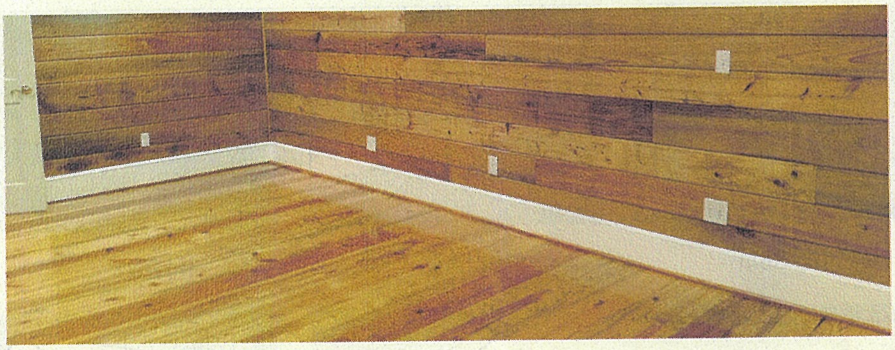


**Figure 6** Common lumber-cutting methods.

### Resurrected Wood

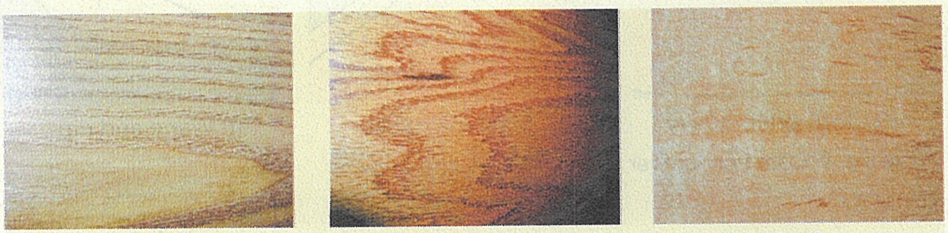
Wood from longleaf pine and bald cypress are prized by carpenters for their outstanding beauty and durability. Unfortunately, clear-cutting that occurred in the late 1800s nearly wiped out those two species from the vast forests and swamps in the southeastern United States. Today, lumber companies have resurrected this wood by retracing the rivers used by timber companies to transport the logs to sawmills. Logs of original-growth pine and bald cypress have been lying along river bottoms for more than one hundred years. What was left behind is now harvested by scuba divers, and then sawn, dried, and used for various construction purposes. The use of this "pecky" cypress has become popular in today's residential structures, as shown in this photo.



*Source:* 3queens_aJack/Shutterstock

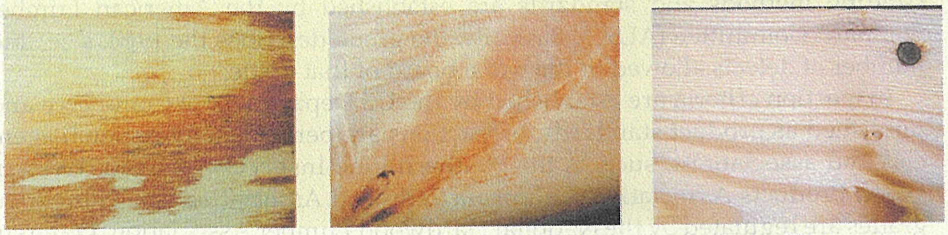
### Hardwoods and Softwoods

Hardwoods and softwoods vary widely in color and grain pattern. Carpenters should be able to recognize common hardwood and softwood species and describe uses for them. Softwoods are typically used for conventional light frame construction.



Ash Oak Maple

**Hardwoods**



Southern yellow pine Nordic pine Fir

**Softwoods**

common uses, a certain number and size of defects are permitted. Unless lumber is severely damaged, some use can be found for practically every piece. *Figure 7* shows various types of lumber defects and damages.

### 2.1.4 Moisture and Shrinkage

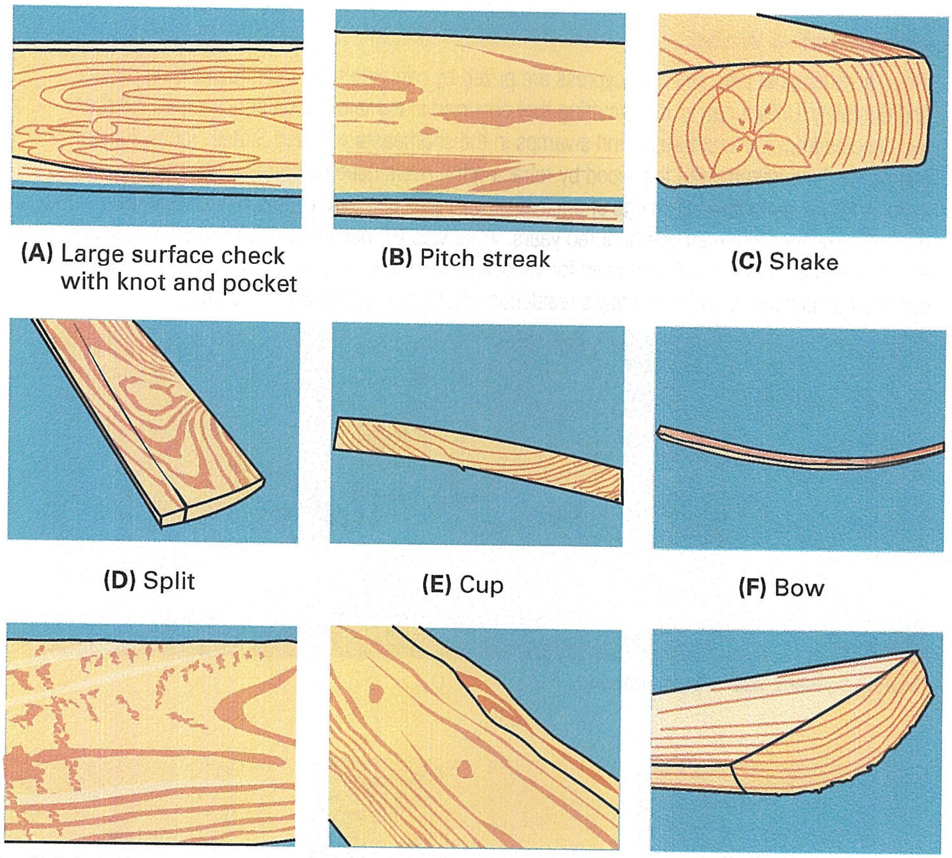
Trees contain a large amount of moisture. For example, a newly cut 10' length of 2×10 lumber can contain more than 4 gallons of water. Due to its high moisture content, freshly cut (green) lumber cannot be used until it is dried. If green lumber is used, it may result in cracked ceilings or floors, squeaky floors, sticking doors, or other problems. Initially, some moisture is removed by heating lumber in kilns at the sawmill. However, the lumber continues to dry for a long time after that. As cut lumber dries, it shrinks, which can cause warping and splitting because the lumber dries unevenly. A carpenter must be able to tell when lumber contains too much moisture. Moisture meters can be used on-site for that purpose. Another simple way to check for moisture is to hit the lumber with a hammer.

### Lumber Shrinkage

Wood is both hygroscopic and anisotropic. Hygroscopic means wood can absorb or shed moisture in the surrounding air. Anisotropic means the wood has different properties depending on the direction of the wood's grain. Having both of these properties means that lumber often does not shrink or expand in a uniform manner. Fortunately, there is a simple rule of thumb carpenters can use to estimate wood shrinkage or expansion: if the moisture content of a board changes by four percent, the board thickness and width will shrink or expand by about one percent. Shrinkage and expansion have little effect on the length of the board.

### Drying Lumber

The two methods of drying lumber are kiln drying and air drying. In kiln drying, moisture is removed from lumber in large temperature-controlled buildings called kilns. In air drying, the lumber is stacked outdoors and allowed to dry for up to three months, as compared with only a few days for kiln drying. Even though the process is much longer, air-dried lumber is still likely to have a higher moisture content than kiln-dried lumber.


**(A)** Large surface check with knot and pocket

**(B)** Pitch streak

**(C)** Shake

**(D)** Split

**(E)** Cup

**(F)** Bow

**(G)** Torn grain-heavy

**(H)** Machine offset

**(I)** Wane and dip

**Figure 7** Common lumber characteristics and defects.

## 2.1.5 Lumber Grading

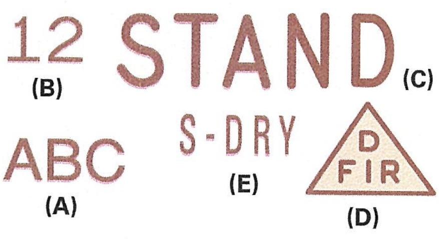
Lumber is graded by inspectors who examine the lumber after it is planed. Grading methods and standards are established by the American Lumber Standard Committee (ALSC). Basically, the grade describes the type, size, and number of defects allowed in the worst board of that grade.

Inspection criteria are established by the US Department of Commerce and published as product standards. Inspections are performed by regional agencies and associations, such as the Southern Pine Inspection Bureau, Western Wood Products Association, California Redwood Association, etc. Hardwood grades are regulated by the National Hardwood Lumber Association. Different associations may have slightly different standards for the numbers and types of defects permitted within a particular grade. Inspectors from accredited inspection agencies examine the lumber, determine the grade in accordance with the association's specifications, and apply the applicable grade stamp. Keep in mind that since grading is done right after the board is planed, it cannot account for warping that might occur if the board is improperly stored.

Carpenters must be familiar with the various lumber grades. The designer, builder, and/or engineer specifies the lumber grades to be used on the job. It is important that the carpenter or contractor buying the lumber purchase the specified grade. To do that, you must be able to read the grade stamp. *Figure 8* shows and explains a typical grade stamp.

Lumber is graded based on its strength, stiffness, and appearance. The highest grades have very few defects; the lowest grades may have knots, splits, and other problems.

Softwood lumber is graded into three major categories: boards, dimension lumber, and timbers. These categories are further divided into specific types of lumber and then classified by appearance (*Table 1*) and strength (*Table 2*). The following is a breakdown of each category:



**(A)** Inspection association trademark.

**(B)** Mill Identification—firm name, brand, or assigned mill number.

**(C)** Grade Designation—grade name, number, or abbreviation.

**(D)** Species Identification—indicates species individually or in combination.

**(E)** Condition of seasoning at time of surfacing:
S-Dry—19% maximum moisture content
MC15—15% maximum moisture content
S-GRN—over 19% moisture content (unseasoned)

**Figure 8** Typical lumber grade stamp.

**TABLE 1** Board Appearance Grades

| Appearance Grade | Product | Grades | Applications |
|---|---|---|---|
| High Quality | Selects | B and Better Select<br>C Select<br>D Select | Used for walls, ceilings, trim, and other areas where appearance is important, but the use of hardwood is not desirable because of cost or other considerations. |
| | Finish | Superior<br>Prime<br>E | |
| | Paneling | Clear (any select or finish grade)<br>No. 2 Common (selected for knotty paneling)<br>No. 3 Common (selected for knotty paneling) | |
| | Siding (bevel, bungalow) | Superior<br>Prime | |
| General Purpose | Boards, Sheathing | No. 1 Common<br>No. 2 Common<br>No. 3 Common<br>No. 4 Common<br>No. 5 Common | Common boards are used for shelving, decking, window trim, and other applications where appearance is less critical, or where on-site selection and cutting is practical when appearance is a consideration. |
| | Alternate Board | Select merchantable<br>Construction<br>Standard<br>Utility<br>Economy | |

**TABLE 2** Grades of Dimensional Lumber and Timbers

| Product | Grades | Uses |
|---|---|---|
| Light Framing<br>2" to 4" thick<br>2" to 4" wide | Construction<br>Standard<br>Utility<br>Economy | Light framing lumber is used where great strength is not required such as for studs, plates, and sills. |
| Studs<br>2" to 4" thick | Stud<br>Economy Stud | This optional grade is intended for vertical use, as in loadbearing walls. |
| Structural Light Framing<br>2" to 4" thick<br>2" to 4" wide | Select Structural<br>No. 1<br>No. 2<br>No. 3<br>Economy | Structural lumber is used for light framing and forming where greater bending strength is required. Typical uses include trusses, concrete pier wall forms, etc. |
| Structural Joists and Planks<br>2" to 4" thick<br>5" to 18" wide | Select Structural<br>No. 1<br>No. 2<br>No. 3<br>Economy | These grades are designed especially for lumber 5 inches and wider and are suitable for use as floor joists, rafters, headers, small beams, trusses, and general flooring applications. |
| Beams and Stringers<br>5" and thicker with this width<br>More than 2" greater than the thickness. | Select Structural<br>No. 1<br>No. 2<br>No. 3 | These grades are used for stringers, beams, posts, and other support members. |
| Posts and Timbers<br>5" × 5" with the width not more than 2" greater than the thickness. | Select Structural<br>No. 1<br>No. 2<br>No. 3 | These grades are used for stringers, beams, posts, and other support members. |

**Sheathing**: Panel material to which roofing material or siding is secured.

**Joists**: Generally, equally spaced framing members that support floors and ceilings.

### Grading Lumber

An understanding of lumber grading is very important to proper building construction. For example, it allows you to communicate effectively about the details of the construction process with others on the jobsite. More importantly, the building drawings specify grades of lumber that should be used for various parts of the structure. You will have to interpret those drawings in order to construct the building properly.

**TABLE 3** Nominal and Dressed (Actual) Sizes of Dimension Lumber (in Inches)

| Nominal | Dressed |
|---|---|
| 2 × 2 | 1½ × 1½ |
| 2 × 4 | 1½ × 3½ |
| 2 × 6 | 1½ × 5½ |
| 2 × 8 | 1½ × 7¼ |
| 2 × 10 | 1½ × 9¼ |
| 2 × 12 | 1½ × 11¼ |

**Millwork**: Manufactured wood products such as doors, windows, and moldings.

- *Boards*—Boards, **sheathing**, and form lumber
- *Dimension lumber*—Light framing, studs, structural light framing, and structural **joists** and planks
- *Timbers*—Beams and stringers

## 2.1.6 Grading Terms

Among the different agencies, criteria for grading may vary somewhat. Generally, all grading agencies use five basic size classifications as follows:

- *Boards (BD)*—Consists of members under 2" thick and 2" wide and wider.
- *Light framing (L.F.)*—Consists of members 2" to 4" thick and 2" to 4" wide.
- *Joists and planks (J&P)*—Consists of members 2" to 4" thick and 5" to 18" wide.
- *Beams and stringers (B&S)*—Consists of members 5" thick and thicker with the width more than 2" greater than the thickness.
- *Posts and timbers (P&T)*—Consists of members 5" × 5" with the width not more than 2" greater than the thickness, approximately square.

For each species and size classification, the grading agencies establish several stress-quality grades, for example, Select structural, No. 1, No. 2, No. 3, and assign allowable stresses for each.

Other lumber terms used in grading are:

- *Nominal size*—The size by which it is known and sold in the market (e.g., 2 × 4), as opposed to the dressed size.
- *Dressed (actual) size*—The dimensions of lumber after surfacing with a planer. The dressed size is usually ½" to ¾" less than the nominal or rough size. A 2 × 4 stud, for example, measures 1½" by 3½". *Table 3* compares nominal lumber sizes to dressed sizes for dimension lumber. Additional data on softwood and hardwood lumber dimensions, including equivalent metric conversions, are provided in *Appendix C*.
- *Dressed lumber*—Lumber that is surfaced by a planer on one side (S1S), two sides (S2S), one edge (S1E), two edges (S2E), or any combination of sides and edges (S1S1E, S1S2E, or S4S). S4S means the wood is surfaced on 4 sides. Dressed lumber may also be referred to as planed or surfaced.
- *Dimension lumber*—Lumber that is supplied in nominal 2", 3", or 4" thicknesses with standard widths. Light framing, studs, joists, and planks are classified as dimension lumber.
- *Matched lumber*—Lumber that is edge- or end-dressed and shaped to make a tongue-and-groove (T&G) joint at the edges or ends.
- *Patterned lumber*—Lumber that is shaped to a pattern in addition to being dressed, matched, or shiplapped, or any combination of these workings.
- *Rough lumber*—Lumber as it comes from the sawmill prior to any dressing or planing operation.
- *Stress-grade lumber*—Lumber grades having assigned working stress and elasticity values in accordance with basic accepted principles of strength grading. Stress is the force exerted on a unit area of lumber, usually expressed in terms of pounds per square inch. Allowable stress is the maximum stress established by the applicable building codes. Allowable stress is always less than the ultimate stress (the amount of stress that can be withstood before the material fails) for obvious structural and safety reasons.
- *Surfaced lumber*—Same as dressed lumber.
- *Framing lumber*—Lumber used for the structural members of a building, such as studs and joists.
- *Finish lumber*—Lumber suitable for **millwork** or for the completion of the interior of a building, chosen because of its appearance or ability to accept a high-quality finish.

- *Select lumber*—In softwoods, a general term for lumber of good appearance and finishing qualities.

Trimming is the act of crosscutting a piece of lumber to a given length.

- Double end-trimmed (DET) lumber is trimmed reasonably square by a saw on both ends.
- Precision-end-trimmed (PET) lumber is trimmed square and smooth on both ends to uniform lengths, with a manufacturing tolerance of 1/16" over or under (+/–) in length in 20 percent of the pieces.
- Square-end-trimmed lumber is trimmed square, permitting only a slight manufacturing tolerance of 1/64" for each nominal 2" of thickness or width.

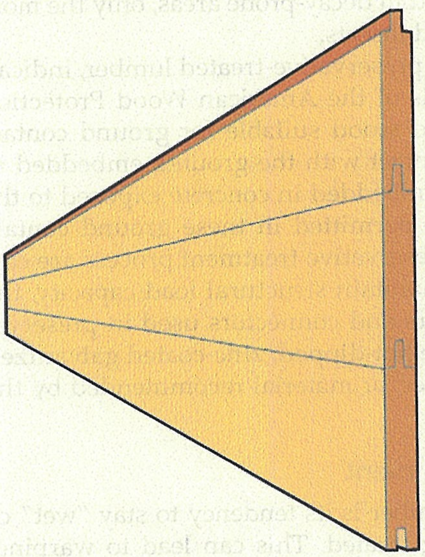
### 2.1.7 Classification of Manufacturing Defects

In some instances, lumber may be damaged when being cut, dressed, or dried. The following describes how manufacturing defects impact lumber grades:

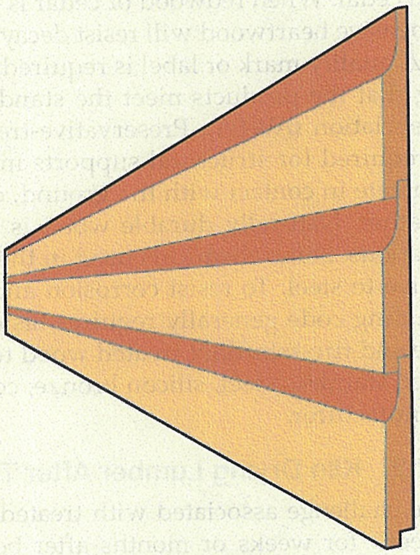
- *Standard A*—Very light torn grain; occasional light chip marks; very slight knife marks.
- *Standard B*—Very light torn grain; very light raised grain; very light loosened grain; slight chip marks; average of one slight chip mark per lineal foot but not more than two in any lineal foot; very slight knife marks; slight mismatch.
- *Standard C*—Medium torn grain; light raised grain; light loosened grain; very light machine bite; very light machine gouge; very light machine offset; light chip marks if well scattered; occasional medium chip marks; very slight knife marks; slight mismatch.
- *Standard D*—Heavy torn grain; medium raised grain; very heavy loosened grain; light machine bite; light machine gouge; light machine offset; medium chip marks; slight knife marks; very light mismatch.
- *Standard E*—Very heavy torn grain; raised grain; very heavy loosened grain; medium machine bite; machine gouge; medium machine offset; chip marks; knife marks; light wavy dressing; light mismatch.
- *Standard F*—Very heavy torn grain; raised grain; very heavy loosened grain; heavy machine bite; machine gouge; heavy machine offset; chip marks; knife marks; medium wavy dressing; medium mismatch.
- *Standard G*—Loosened grain; raised grain; torn grain; machine bite; machine burn; machine gouge; machine offsets; chip marks; medium wavy dressing; mismatch.

**Calculating Dressed Softwood Lumber Sizes**

As shown in *Table 3*, nominal lumber sizes are different than the actual, or dressed, dimensions of the board or lumber. A general rule can be applied when calculating dressed sizes of softwood boards. Boards with nominal dimensions less than 1" have dressed dimensions that are 1/4" smaller. Boards with a nominal width of 2" to 6" usually have dressed dimensions that are 1/2" smaller. For boards with widths greater than 6", subtract 3/4" from the nominal dimensions to determine the dressed dimensions. Remember, this is a general rule and may not be accurate in every case. The best way to verify lumber dimensions is to perform an actual measurement, but remember that the size may change depending on the moisture content of the wood.



Tongue-and-groove siding



Shiplap siding

**Matched vs. Patterned Lumber**

Matched lumber is end- or edge-dressed to create a smooth joint with another piece of lumber. Tongue-and-groove siding is an example of matched lumber that is edge-dressed. Patterned lumber is shaped to a pattern in addition to being dressed or matched. Shiplap siding is a type of patterned lumber in which the two pieces are tapered opposite each other so that when joined together, they form a smooth overlapping joint.

### Abbreviations

Most contract documents and construction drawings use abbreviations to convey information to a craftworker. *Appendix D* lists the common abbreviations used by the Southern Forest Products Association when referring to pine lumber. Many of them also hold for the other wood species.

## 2.2.0 Treated Lumber

Carpenters regularly use treated lumber and plywood. As a result, it is important to understand the differences between the available types.

### 2.2.1 Decay Protection

Most types of wood will deteriorate when they have been exposed to excess moisture or when they are in contact with the ground for extended periods of time. When building in locations subject to decay, use durable wood or wood treated with preservatives. Heartwood of decay-resistant redwood, cedar, black locust, and black walnut are considered naturally durable. Wood preservatives are commonly applied to the lumber to protect it against decay and termites. Preservatives are also applied through pressure and nonpressure methods.

Wood preservatives commonly used for construction lumber are waterborne preservatives such as chromated copper arsenate (CCA), alkaline copper quaternary (ACQ) and sodium borates (SBX). CCA-treated lumber is no longer permitted for use in residential and consumer-related applications. However, CCA-treated lumber can be used for industrial, highway, and agricultural applications such as poles, guardrail posts, and saltwater marine exposures. Quality stamps for treated wood, printed directly on the wood or attached to the ends of the lumber, provide information regarding the type of preservative and retention.

**Sill plates**: Horizontal members that support the framework of a building on the bottom of a wall or box joist. Also called sole plates.

Preservative-treated (PT) lumber is softwood lumber protected by chemical preservatives forced deep into the wood through a vacuum-pressure process. This type of lumber has been used for many years for on-ground and below-ground applications such as landscape timbers, **sill plates**, and foundations. In some parts of the country, PT lumber is used extensively for decks, porches, docks, and other outdoor structures subject to decay from exposure to the elements. It is also popular in areas where structures are exposed to insect or fungus attacks. A major advantage of preservative-treated lumber is its relatively low price in comparison with naturally durable species such as redwood and cedar. When redwood or cedar is used in decay-prone areas, only the more expensive heartwood will resist decay and insects.

A quality mark or label is required on preservative-treated lumber, indicating that the products meet the standards of the American Wood Protection Association (AWPA). Preservative-treated wood suitable for ground contact is required for structural supports in contact with the ground, embedded in concrete in contact with the ground, or embedded in concrete exposed to the weather. Naturally durable wood is not permitted in these ground contact locations. Some chemicals used in the preservative treatment process are corrosive to steel. To resist corrosion and maintain structural load capacity, the building code generally requires fasteners and connectors used in preservative and fire-retardant treated wood to be hot-dipped, zinc-coated galvanized steel, stainless steel, silicon bronze, copper, or material recommended by the manufacturer.

### 2.2.2 Kiln Drying Lumber After Treatment

One challenge associated with treated lumber is its tendency to stay "wet" or "green" for weeks or months after being treated. This can lead to warping, cupping, and other issues as it begins to dry. To alleviate this problem, many lumber manufacturers have begun kiln drying the wood immediately after pressure treating it. **Kiln Dried After Treatment (KDAT)** wood is stacked in a kiln and dried using controlled temperatures and airflow. Ultimately, this process removes up to 80 percent of the moisture in the treated wood and greatly reduces challenges associated with shrinkage.

**Kiln Dried After Treatment (KDAT):** Lumber dried in a kiln after it has been pressure treated. This process can alleviate warping and cupping problems associated with drying pressure-treated lumber over a longer period of time.

### 2.2.3 Fire-Retardant Treated

Lumber and panel materials are sometimes treated with fire-retardant chemicals. The lumber or panels can either be coated with the chemical in a nonpressure process or impregnated with the chemical in a pressure-treatment process. Fire-retardant chemicals react to extreme heat and form a protective coating around the outside of the wood. This coating, known as *char,* delays ignition and inhibits the release of smoke and toxic fumes.

Fire-retardant treated OSB provides greater burn-through resistance than common OSB panels, and is commonly used as a roof or wall sheathing. Fire-retardant treated panels are coated with a noncombustible, inert material (typically magnesium oxide) and water mixture that is chemically bonded to the OSB. When the panels are exposed to intense heat, the water is released, resisting the burn-through and slowing the spread of flames. Fire-retardant treated panels have a special grade stamp.

Before cutting OSB, be sure to check the applicable SDS for safety hazards. The SDS is the most reliable source for safety information.

**CAUTION**

Whenever working with older materials that may contain asbestos, contact your supervisor for the company's policies on safe handling of the material. Due to potential dangers associated with airborne dust from asbestos, state and federal regulations require you to follow specific procedures prior to and during removal, cutting, or distribution of these types of materials. Check the SDS before cutting.

## 2.3.0 Engineered Wood Products

Engineered wood products are a general classification of wood building materials manufactured from solid and reconstituted wood products and byproducts. The wood products and byproducts are combined with adhesives, **resins**, and other binders, then pressed under extreme heat and pressure to form panel and lumber products. Engineered wood products are as strong and dimensionally stable as their solid wood counterparts.

Engineered wood products can be divided into two major categories: wood structural panel products and nonpanel products. Panel products include plywood, hardboard, particleboard, oriented strand board (OSB), and fiberboard. Nonpanel products can be divided into several classifications: structural composite lumber (SCL), which includes laminated **veneer** lumber (LVL); parallel strand lumber (PSL); and laminated strand lumber (LSL). Wood I-joists, glued laminated timber (glulam), and a relatively new product to North America called cross-laminated timber (CLT), are also available. Metal plate-connected wood trusses are used in floor and roof systems. Engineered wood products provide several benefits:

- They can be made from younger, more abundant trees.
- They can increase the yield from a tree by 30 percent to 50 percent.
- They are stronger than the same size of structural lumber.
- Greater strength allows the engineered lumber to span a greater distance.
- A length of engineered wood is typically lighter than the same length of solid lumber. It is therefore easier to handle.
- They are dimensionally accurate and do not warp, crown, or twist.

**Resins**: Protective natural or synthetic coatings.

**Veneer**: Used in the manufacture of wood structural panels. Veneers and wood strands or wafers are bonded together with resins and other bonding systems.

### 2.3.1 Wood Structural Panels

Wood structural panels are manufactured from veneers or wood strands. Examples of wood structural panels include plywood and oriented-strand board (OSB). The standard size of a wood structural panel is 4' × 8'. Other panel sizes, ranging from 6' to 8' widths and up to 16' lengths, are also available on special order.

#### Wood Structural Panel Grades

After the wood structural panels have been manufactured, they are graded. The grading procedure is similar to the grading of lumber. The grade stamp that appears on each panel lists the grade. *Table 4* shows examples of applications for wood structural panels.

**TABLE 4** Guide to Wood Structural Panel Use

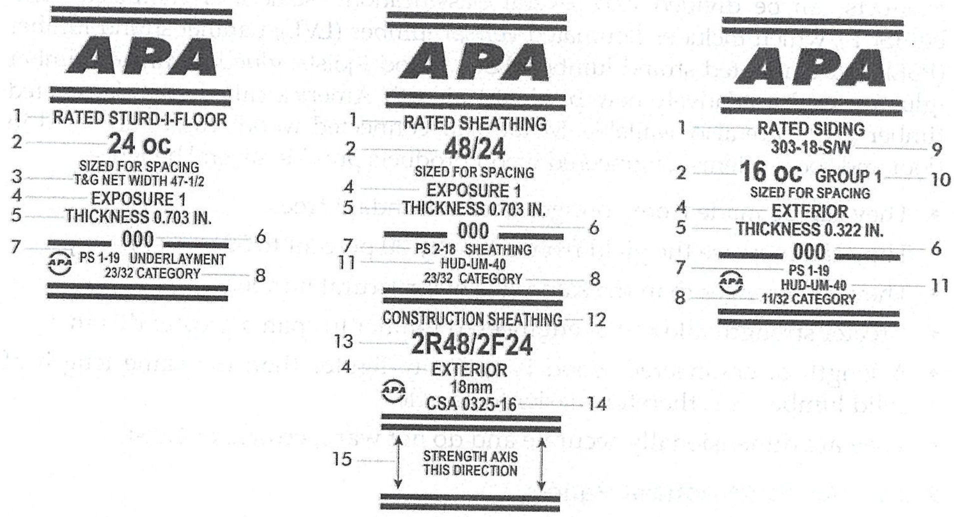
| Panel Grade and Bond Classification | Description and Application | Common Performance Category (in.) | Panel Construction | |
|---|---|---|---|---|
| | | | **OSB** | **Plywood Minimum Veneer Grade** |
| Sheathing<br>EXP 1 | Unsanded sheathing grade for wall, roof, subflooring, and industrial applications such as pallets and for engineering design with proper capacities. | 5/16, 3/8, 15/32, 1/2, 19/32, 5/8, 23/32, 3/4 | Yes | Yes |
| Structural 1 Sheathing<br>EXP 1 | Panel grades to use where shear and cross-panel strength properties are of maximum importance. Plywood Structural 1 is made from all Group 1 woods. | 3/8, 7/16, 15/32, 1/2, 19/32, 5/8, 23/32, 3/4 | Yes | Yes |
| Single Floor<br>EXP 1 | Unsanded sheathing grade for wall, roof, subflooring, and industrial applications such as pallets and for engineering design with proper capacities. | 19/32, 5/8, 23/32, 3/4, 7/8, 1, 1 3/32, 1 1/8 | Yes | Yes |

### Evolution of Wood Products

In the past, the primary source of structural beams, timbers, joists, and other loadbearing lumber was old-growth trees. These trees, which need many decades to mature, are tall and thick and can produce a large amount of high-quality, tight-grained lumber. Extensive logging of these trees to meet demand resulted in higher prices and conflict with forest conservation interests. The development of wood-laminating techniques by lumber producers has permitted the use of younger-growth trees in the production of structural building materials.

Wood structural panels are rated for interior or exterior use. Exterior-rated panels are used for sheathing, siding, and other applications where there may be exposure to moisture or wet weather conditions. Interior plywood uses lower grades of veneer for the back and inner plies. Although the plies can be bonded with a water-resistant glue, waterproof glue is normally used. The lower-grade veneers reduce the bonding strength, however, which means that interior-rated panels are not suitable for exterior use.

The APA–Engineered Wood Association *Grades and Specifications* is the one guide for wood structural panel grading. Different grade stamps are used for various types of panels (*Figure 9*). Sanded plywood panels are panels with B-grade or better face veneers, which are sanded smooth during manufacture. Performance-rated panels, also known as structural panels, include three grades: Rated Sheathing, Rated Sturd-I-Floor®, and Rated Siding. Rather than listing the face veneer grade, grade marks for performance-rated panels include information on the panel grade, thickness, and span rating. Always be sure to check the project specifications for grades.



1. Panel grade
2. Span rating
3. Tongue and groove
4. Bond classification
5. Decimal thickness declaration
6. Mill number
7. Product standard
8. Performance category
9. Sliding face grade
10. Species group number
11. HUD recognition
12. Panel grade, Canadian standard
13. Panel mark
14. Canadian construction sheathing standard
15. Panel face orientation

**Figure 9** Performance-rated panel grade stamps.

*Source:* **https://www.apawood.org/apa-trademark.**
Owned by APA – The Engineered Wood Association

## Oriented Strand Board (OSB)

OSB is manufactured with thin rectangular wood strands arranged in cross-aligned layers, similar to plywood. Additionally, it is arranged in five or more cross-banded layers (*Figure 10*) and bonded with phenolic resin under intense heat and pressure. OSB can be used interchangeably with plywood for almost all applications.

OSB is used for wall and roof sheathing and single-layer floor construction. It provides dimensional stability, stiffness, fastener holding capacity, and no core voids. OSB panels may be sprayed with a surface treatment to provide additional qualities. For example, OSB panels used for roof sheathing may have a reflective coating applied to the underside to provide a higher fire rating, or a nonskid surface may be applied to the top side for better traction for workers on the roof.

## Plywood

Plywood is made of layers (plies) of wood veneers, which may be 1⁄16" to 5⁄8" thick. The center layer is known as the core. As layers are added on either side of the core, they are placed alternately at right angles, which increases the strength of the panel. Layers with the grain at right angles to the core are called crossbands. The outer exposed layer is known as the face veneer.

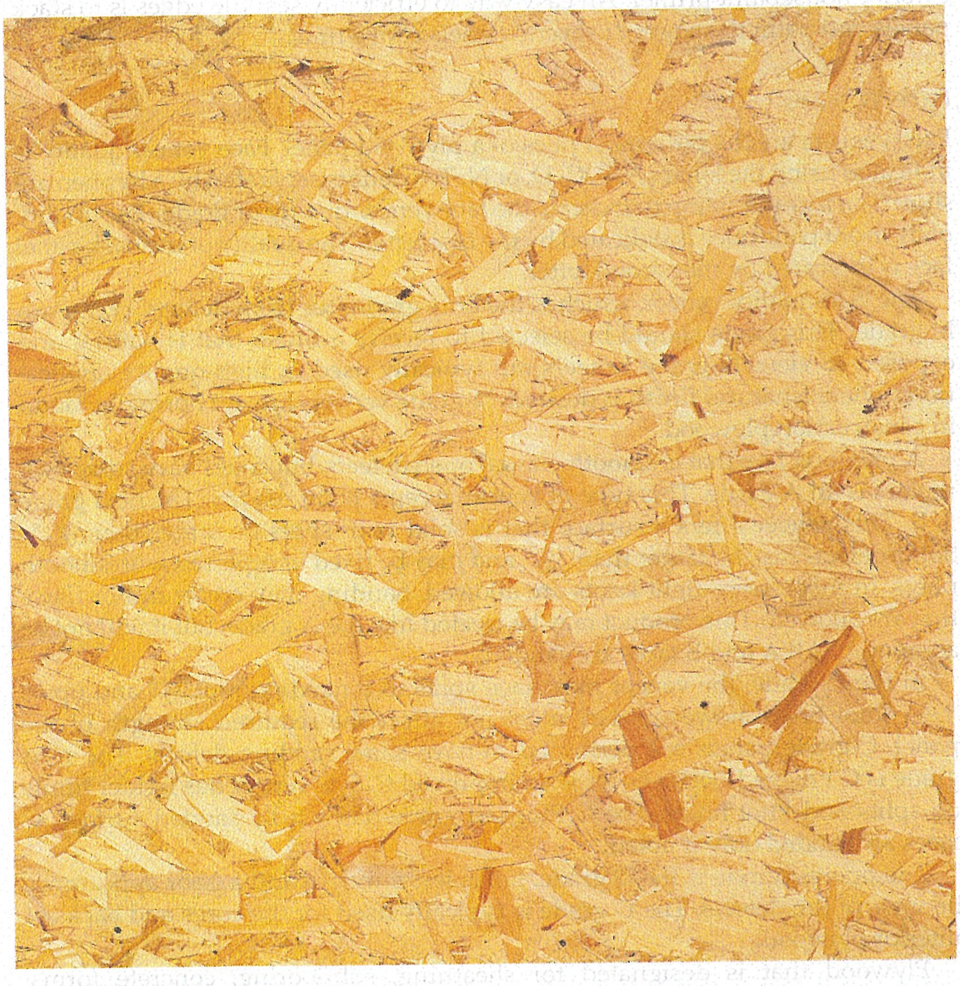


**Figure 10** OSB texture and appearance.
*Source:* Dymaxfoto/Shutterstock

Plywood panel thickness varies from $\frac{3}{16}$" to $1\frac{1}{4}$". Common sizes are $\frac{1}{4}$", $\frac{1}{2}$", and $\frac{5}{8}$" for finish paneling and $\frac{3}{8}$", $\frac{1}{2}$", $\frac{5}{8}$", and $\frac{3}{4}$" for some structural purposes. The three types of edges on plywood are as follows:

- **Butt joint** (two standard pieces joined)
- A **shiplap** cut or edge
- Interlocking tongue-and-groove

Opposite edges or all four edges may be cut to match.

**Butt joint**: The joint formed when one square-cut edge of a piece of material is placed against another material.

**Shiplap**: A method of cutting siding in which each board is tapered and grooved so that the upper piece fits tightly over the lower piece.

### High-Density Overlay (HDO) and Medium-Density Overlay (MDO) Plywood

High-density overlay (HDO) plywood panels have a hard, resin-impregnated fiber overlay heat-bonded to both surfaces. HDO panels are abrasion- and moisture-resistant, and can be used for concrete forms, cabinets, countertops, and similar high-wear applications. HDO plywood also resists damage from chemicals and solvents. HDO plywood panels are available in five common thicknesses: $\frac{3}{8}$", $\frac{1}{2}$", $\frac{5}{8}$", $\frac{3}{4}$", and 1".

Medium-density overlay (MDO) plywood panels are coated on one or both surfaces with a smooth, opaque overlay. MDO plywood accepts paint well and is very suitable for use as structural siding, exterior decorative panels, and soffits. MDO plywood panels are available in eight common thicknesses ranging from $\frac{1}{32}$" to $2\frac{3}{32}$".

Both HDO and MDO panels are manufactured with waterproof adhesive and are suitable for exterior use. If MDO panels are to be used outdoors, however, the panels should be edge sealed with one or two coats of a good-quality exterior housepaint primer. An easy way to efficiently seal the edges is to stack panels and paint the edges of several panels at one time.

### Face Veneers

Face veneers are the outermost plies of a plywood panel. Face veneer quality is indicated using the letters A, B, C, D, or N. Two letters separated by a hyphen are shown on a grade stamp to indicate the face veneer quality or grade. The quality of the front panel face is indicated by the first letter. The quality of the back panel face is indicated by the second letter.

The best-quality veneer, which is the only grade free from defects, carries an N grade. This grade should be selected to receive a finish that is natural and exposed to view. N-grade veneers are typically used in high-quality applications where a natural finish is desired. N-grade veneers are not normally found in construction plywood.

A plywood face that is smooth, has no open defects, but could have some heat repairs is an A grade. This type of veneer accepts paint readily. The next grade is B. This veneer offers a surface that is solid with splits no larger than $\frac{1}{32}$". Some defects may be larger than $\frac{1}{32}$" and may be fixed or repaired with smooth plugs. In most cases, tight knots are allowed. Sanding may create minor flaws that are allowed. This product may be treated like the A grade, but it will not be as smooth. All A and B faces are sanded.

In the C grade, the veneer may have splits to a maximum of $\frac{1}{2}$" and up to $1\frac{1}{2}$" knot holes; however, they must not affect the required strength of the panel. C-grade panels are permitted to have some sanding defects. The next grade is C Plugged. This veneer is an improved C. The veneer has tighter limits on splits and knot holes. The C Plugged grade has a fully sanded surface. C faces are sanded only if noted.

The poorest grade is the D grade. It has less strength and a poor appearance because of the defects. The D grade is typically used for the cores and backs of interior plywood.

Plywood that is designated for sheathing, subflooring, concrete forms, and panels used for special structural purposes is called performance-rated

### Selecting Plywood

Plywood that is expressly manufactured for either interior or exterior use may be used for other purposes in certain situations. Some local codes may require the use of preservative-treated plywood for exterior construction, in bathrooms, or in other high-moisture areas of a house. Preservative-treated plywood can withstand moisture better than interior plywood. Always check the local code(s) before beginning any construction project.

plywood. The veneers are either unsanded or lightly sanded. The plywood sheets carry slightly different grade markings. The face veneers are either C-C or C-D.

### Hardwood Plywood

Plywood used in the manufacture of cabinets, doors, furniture, and finished components is known as hardwood plywood. Hardwood plywood uses a different grading system than the one described here.

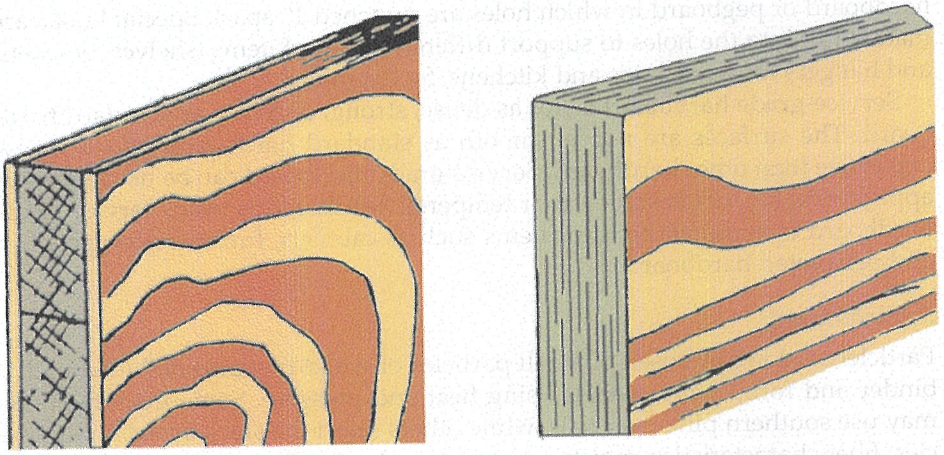
This type of plywood may have any of the following four different types of cores:

- Lumber core
- Particleboard core
- Veneer core (common in softwood plywood)
- Fiberboard core

The type of core will not be indicated on the grade stamp, but one can easily tell by looking at the edge of the plywood (*Figure 11*).

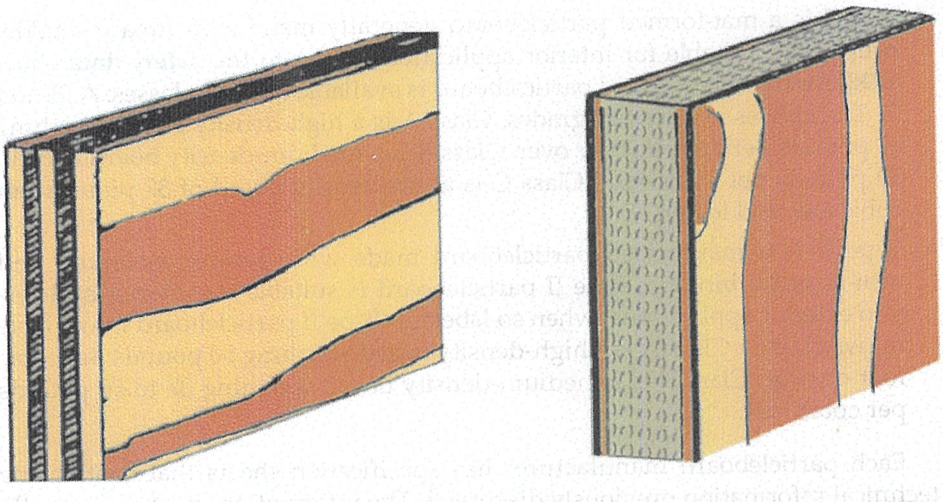
### Hardboard

While plywood uses full sheets of veneers in manufacture, other engineered panel products, such as hardboard, particleboard, oriented strand board, and



Lumber core

Particleboard core



Veneer core

Fiberboard core

**Figure 11** Types of plywood cores.

fiberboard, use vegetable or mineral fibers, as well as waste sawdust, wood chips, and wood scraps, as their main ingredients. The ingredients are softened with heat and moisture, and a binder is added to the mixture. The mixture is then passed through a press, which uses heat and pressure to produce hardboard to the density and thickness desired by the manufacturer.

Hardboard is a manufactured building material, sometimes known as tempered board or pegboard. Hardboard is extremely dense. Common thicknesses for hardboard are 3⁄16", 1⁄4", and 5⁄16". The standard hardboard panel size is 4' × 8'; however, hardboard can be manufactured in widths up to 6' and lengths up to 16' for specialized uses.

Hardboard is water resistant, but its edges are susceptible to breaking if they are not properly supported. Holes must be predrilled for nailing; direct nailing into hardboard causes it to fracture.

Three grades of hardboard are available: standard, tempered, and service grade. Standard hardboard is light brown in color, smooth, and can easily accept paint. Standard hardboard is suitable only for interior use such as cabinets.

Tempered hardboard, commonly known as Masonite™, is manufactured in a similar manner as standard hardboard, but the hardboard is coated with oils and resins, and heated or baked to a dark brown color. In this process, the tempered hardboard becomes denser, stronger, and more brittle. Tempered hardboard is suitable for either interior or exterior uses such as siding, wall paneling, and other decorating purposes. One type of tempered hardboard is perforated hardboard or pegboard in which holes are punched 1" apart. Special hooks are made to fit into the holes to support different types of items (shelves, brackets, and hangers for workshops and kitchens, for example).

Service-grade hardboard is not as dense, strong, or heavy as standard hardboard. The surfaces are not as smooth as standard hardboard, and it is less expensive than other hardboard. Service-grade hardboard can be used for most applications for which standard or tempered hardboard is used. Service-grade hardboard is manufactured for items such as cabinets, furniture components, and perforated hardboard.

**Going Green**

**Housewrap**

Housewrap is a translucent plastic sheet material that is installed over exterior wall sheathing before windows and doors are installed. Housewrap prevents air and water infiltration, while allowing the building to breathe. Water vapor and gases can escape from the building's interior through the walls without trapping moisture in the walls.

## Particleboard

Particleboard is composed of small particles of wood that are combined with a binder and formed into panels using heat and pressure. Some manufacturers may use southern pine materials, while others select the stock based on its species, fiber characteristics, moisture content, and color. The two types of particleboard are as follows:

- Type I is a mat-formed particleboard generally made with urea formaldehyde resin, suitable for interior applications. Refer to the **safety data sheet (SDS)** for handling. Type I particleboard is available in three classes: A, B, and C. The classes are density grades. Class A is a high-density board weighing 50 pounds per cubic foot or over. Class B is a medium-density board of 37 to 50 pounds per cubic foot. Class C is a low-density board of 37 pounds per cubic foot and lower.
- Type II is a mat-formed particleboard made with durable moisture- and heat-resistant binders. Type II particleboard is suitable for interior and certain exterior applications (when so labeled). Type II particleboard is available in two classes: Class A is a high-density board weighing 50 pounds per cubic foot or over; Class B is a medium-density board weighing 37 to 50 pounds per cubic foot.

**Safety data sheet (SDS)**: A document that must accompany any hazardous substance. The SDS identifies the substance and gives the exposure limits, the physical and chemical characteristics, the kind of hazard it presents, precautions for safe handling and use, and specific control measures.

Each particleboard manufacturer has specification sheets that contain the technical information previously discussed. The information sheets are usually available from a local lumber dealer.

Particleboard panels range in size from 1⁄4" to 1 1⁄2" in thickness and from 3' to 8' in width. Panels with thicknesses of 3" and lengths ranging up to 24' are available for special purposes. Particleboard has no grain, is smoother than plywood, is more resilient, and is less likely to warp. It has many uses, especially for shelving and cabinets. In some situations, ¼" particleboard is used as a core for plywood panels.

Some types of particleboard can be used for underlayment if permitted by the local building code. If particleboard is used as underlayment, it should be placed with the long dimension across the joists and the edges staggered. Particleboard can be nailed, although some types of particleboard will crumble or crack when nailed close to the edges.

### Mineral Fiberboards

Glass and gypsum rock are the most common materials used in the manufacture of mineral fiberboards. Glass fibers or gypsum powder are mixed with a binder and pressed or sandwiched between two layers of asphalt-impregnated paper, producing a rigid insulation board. Mineral fiberboard will not support combustion and will not burn.

**Gypsum:** A chalky material that is a main ingredient in plaster and gypsum board.

Certain types of mineral fiberboard have chemical foam mixed with the glass fibers to make a good, rigid insulation. However, this mineral insulation will crush and should not be used when it must support a heavy load.

## 2.3.2 Nonpanel Products

Structural composite lumber (SCL) is a nonpanel product that includes laminated veneer lumber (LVL), parallel strand lumber (PSL), and laminated strand lumber (LSL).

### Laminated Veneer Lumber (LVL)

Like plywood, LVL (*Figure 12*) is made from laminated wood veneers. Douglas fir and southern pine are the primary sources. Thin ($\frac{1}{10}$" to $\frac{3}{16}$") sheets are peeled from the tree in widths of 27" or 54". The veneers are laid up in a staggered pattern with the veneers overlapping to increase strength. Unlike plywood, the grain of each layer runs in the same direction as the other layers. The veneers are bonded with an exterior-grade adhesive, then pressed together and heated under pressure.

LVL is used for floor and roof beams and for the support members called headers that are used over window and door openings. It is also used in scaffolding and concrete forms. No special cutting tools or fasteners are required.

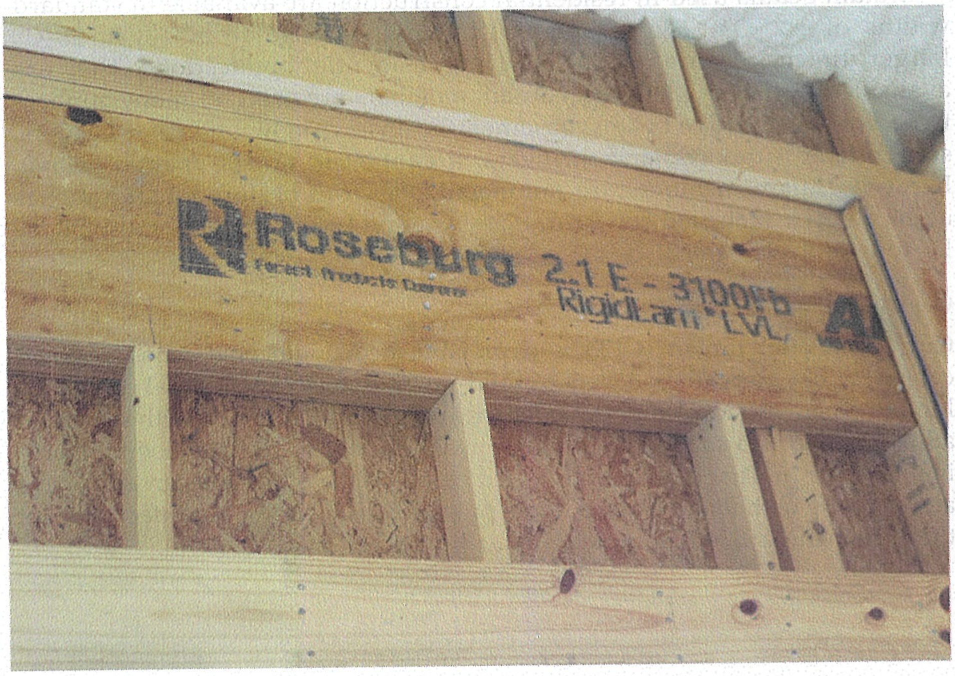


**Figure 12** Rigidlam® LVL.

**Use of Engineered Wood Products**

Engineered wood products are used in a wide array of applications that were once exclusively served by solid lumber. For example, PSL is used for columns, ridge beams, girders, and headers. LVL is also used to form headers and beams. Wood I-joists are used to frame roofs as well as floors. An especially noteworthy application is the use of LSL studs, top plates, and sill plates in place of lumber to frame walls.

### Parallel Strand Lumber (PSL)

**Rafters:** Sloping structural members of a roof frame to which sheathing is secured.

PSL is made from long strands of Douglas fir and southern pine. The strands are about ⅛" or 1⁄10" thick and are bonded together with waterproof adhesive in a special heating process. PSL is used for beams, posts, studs, **rafters**, and columns. It is manufactured in thicknesses up to 7". Columns can be up to 7" wide. Beams range in size up to 18" in width.

### Laminated Strand Lumber (LSL)

LSL is manufactured from small logs of almost any species of wood. Aspen, red maple, and poplar that cannot be used for standard lumber are commonly used for LSL. In the manufacturing process, the logs are cut into short strands, which are bonded together and pressed into long blocks (billets) up to 5½" thick, 8' wide, and 40' long.

LSL is used for millwork such as doors and windows and any other product that requires high-grade lumber. However, LSL will not support as large a load as a comparable size of PSL because PSL is made from stronger wood.

### Wood I-Joists

Wood I-joists, also known as *wood I-beams* (*Figure 13*), consist of a web with flanges bonded to the top and bottom. This arrangement, which mimics a steel I-beam, provides exceptional strength. The webs are made of OSB or plywood and the flanges are grooved to fit over the web. Wood I-joists are most commonly used for floor and ceiling joists and for rafters in residential and commercial construction. Because of their strength, wood I-joists can be used in greater spans than a comparable length of dimension lumber. Lengths of up to 60' are available.

### Glued Laminated Timber (Glulam)

Glulam is manufactured from lengths of solid, kiln-dried lumber that are glued together. Glulam is popular in architectural applications where exposed beams are used (*Figure 14*). Glulam is available in three appearance grades: industrial, architectural, and premium. Industrial grade is used in open buildings such as warehouses and garages where appearance is not a priority or where beams are not exposed. Architectural grade is used where beams are exposed and appearance is important. Premium, the highest grade, is used where the highest-quality appearance is needed (*Figure 15*).

Glulam beams used in residential construction are available in standard widths of 3⅛",3½",5⅛",5½" and 6¾". Depths range from 5½" to 28½". Larger dimensions are available for nonresidential applications. They are available in very long lengths. Glulam members are used for many applications, including ridge beams; basement beams; window and door headers; stair treads, supports, and stringers; a **cantilever**; and a **vaulted ceiling**. Because glulam members are laminated, they can be formed into arches and a variety of curved configurations. Glulam beams are especially popular for use in churches.

**Cantilever:** A beam, truss, or slab (floor) that extends past the last point of support.

**Vaulted ceiling:** A high, open ceiling that generally follows the roof pitch.

### Cross-Laminated Timber (CLT)

Cross-laminated timber (CLT) is a prefabricated engineered wood product consisting of at least three layers of solid-sawn lumber or structural composite lumber where the adjacent layers are cross-oriented and bonded with structural adhesive to form a solid wood element like the one shown in the floor and ceiling in *Figure 16*. Panels are prefabricated based on the project design and arrive at the jobsite with windows and doors pre-cut. Size varies by manufacturer, but they can include 3, 5, 7, or more layers.

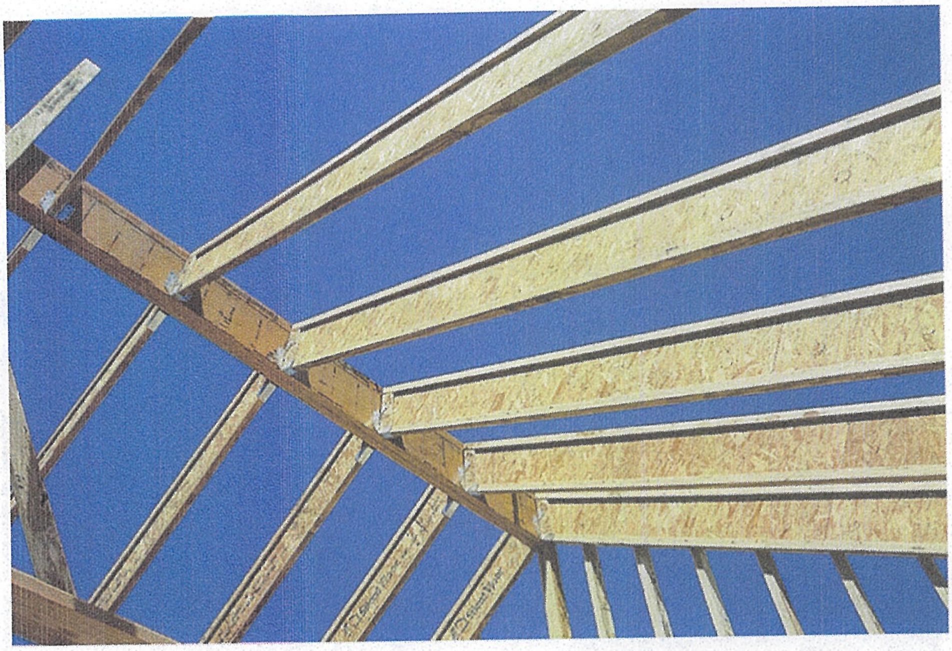


**Figure 13** Wood I-joists.

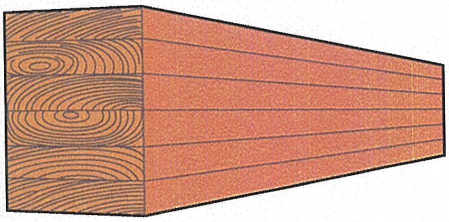


**Figure 14** Glulam beam construction.

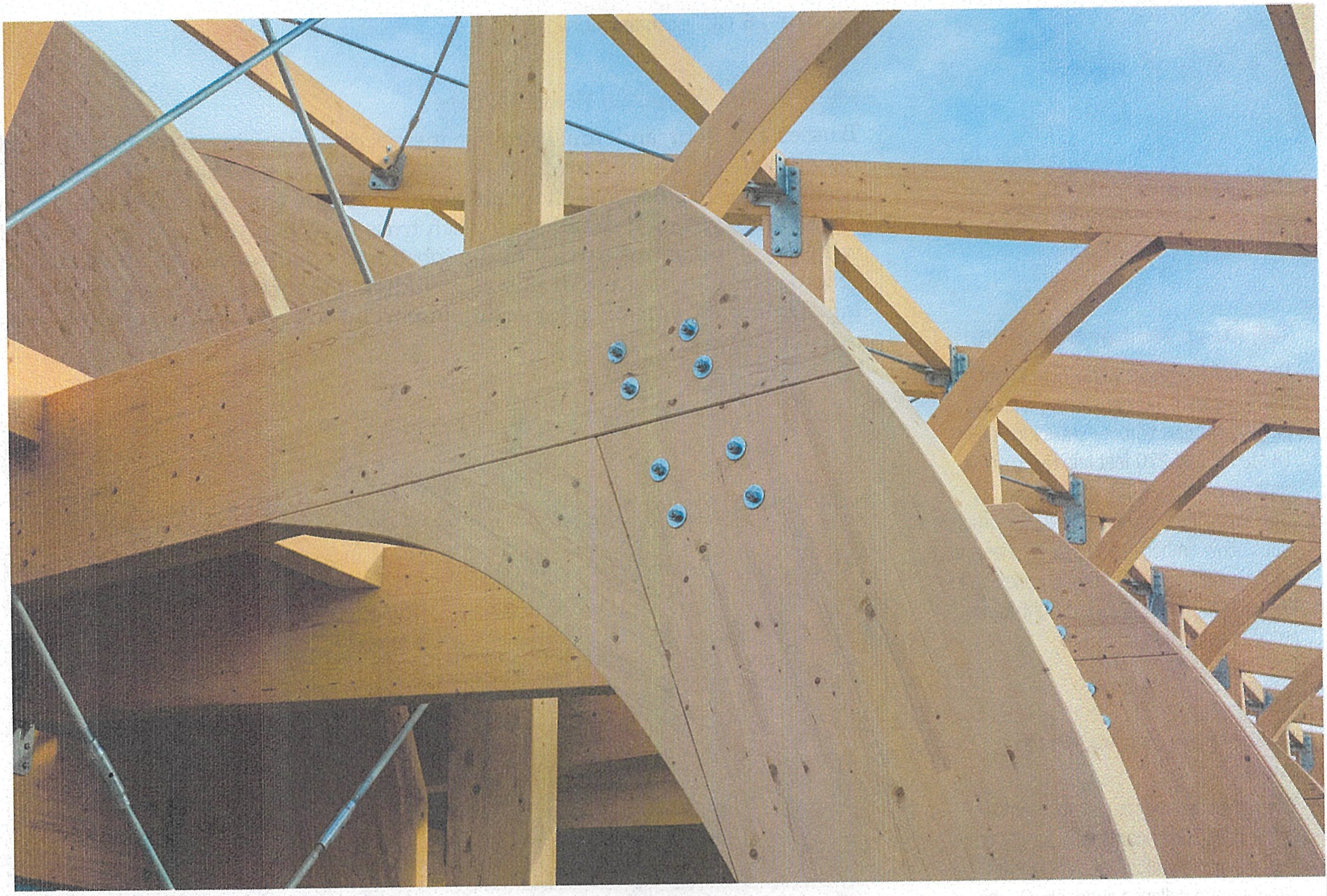


**Figure 15** Glulam architectural beam application.

*Source:* Roberto Sorin/Shutterstock

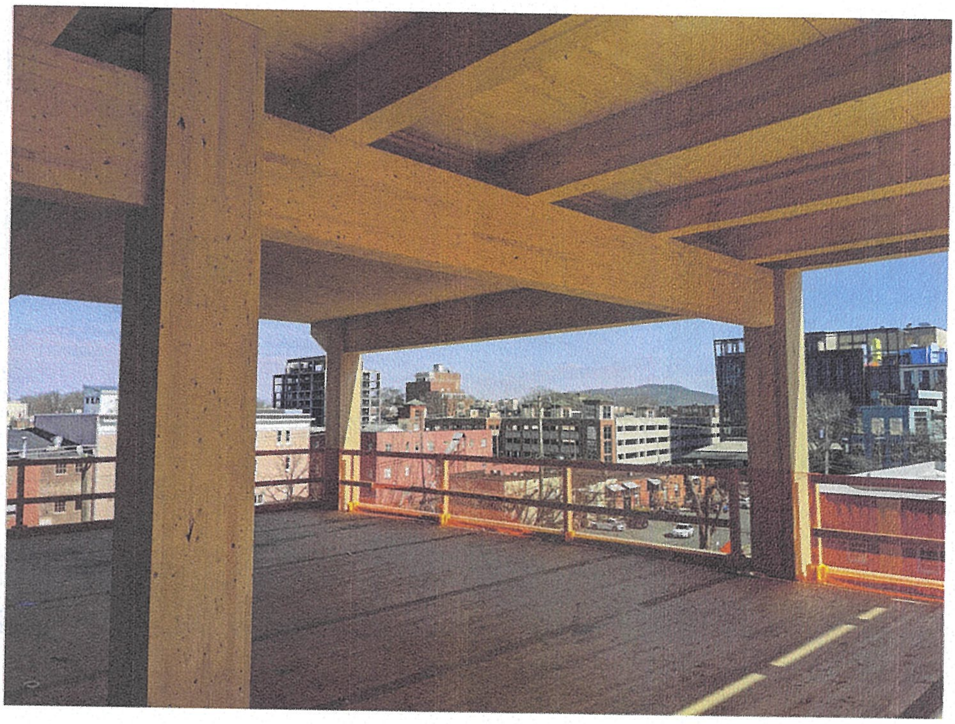


**Figure 16** CLT construction.

### Metal Plate Connected Wood Trusses

Trusses are floor and roof framing members comprising light-frame wood materials (e.g., 2 × 4, 2 × 6, 2 × 8) typically joined together with metal connector plates like the ones shown in *Figure 17*. Wood trusses are designed by an engineer. Engineered drawings of each truss used in a structure are provided with the shipment of trusses to the jobsite. The trusses must be installed in accordance with the truss drawings including temporary and permanent bracing. Temporary bracing is especially important to prevent injury during truss installation.

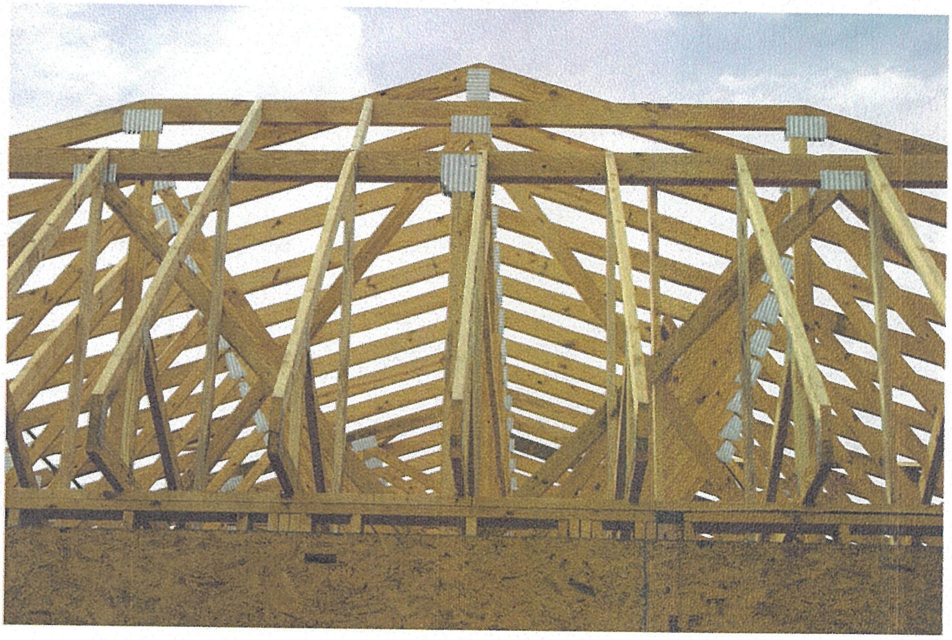


**Figure 17** Connector plates on prefabricated trusses.

### Tall Mass Timber Buildings

The 2021 International Building Code® (IBC®) includes new provisions allowing the use of mass timber in buildings up to 18 stories and 270 feet tall. Using cross-laminated timber (CLT), glulam, SCL, or other mass timbers, these new construction types allow timber to be used in taller and larger buildings than previously allowed in the code for heavy timber or light-frame wood construction.

### Glulam Beams vs. Steel Beams

When exposed to fire, glulam beams outperform steel beams for a longer time. Unprotected metal will quickly lose its strength and collapse suddenly. On the other hand, wood will typically lose its strength slowly because of the protective char layer formed.

## 2.4.0 Concrete Materials

Concrete is commonly used in all types of construction. Concrete is a mixture of three basic materials: portland cement, aggregates, and water. Concrete begins to cure as soon as it is placed. When first mixed, concrete is in a semiliquid state and is referred to as **plastic concrete**. When the concrete hardens but has not yet gained structural strength, it is called **green concrete**. After concrete has hardened and gained its structural strength, it is called **cured concrete**, although the complete curing process may take days, weeks, or even months, depending on the concrete's thickness, temperature, humidity, water content, and other factors.

**Plastic concrete**: Concrete when it is first mixed and is in a semiliquid and moldable state.

**Green concrete**: Concrete that has hardened but has not yet gained its structural strength.

**Cured concrete**: Concrete that has hardened and gained its structural strength.

### 2.4.1 Portland Cement

Portland cement—commonly referred to as *cement*—is a finely ground powder consisting of varying amounts of lime, silica, alumina, iron, and other trace components. While dry, it may be moved in bulk or can be bagged in moisture-resistant sacks and stored for relatively long periods of time. Portland cement is considered **hydraulic** because it sets and hardens by reacting with water and does so with or without the presence of air. This chemical reaction is called **hydration**, and it can occur even when the concrete is submerged in water.

**Hydraulic**: Refers to concrete that sets and hardens by reacting with water.

**Hydration**: The catalytic action water has in transforming the chemicals in portland cement into a hard solid. The water interacts with the chemicals to form calcium silicate hydrate gel.

### 2.4.2 Concrete

Concrete is made of cement and aggregate. **Aggregate** is typically composed of sand, gravel, crushed stone, **slag**, and other coarse and fine materials. Aggregates make up 60 percent to 80 percent of the volume of concrete and function not only as filler material, but also provide strength and reduce volume shrinkage as the concrete cures. When water is added to the cement mixture, the **curing** process begins and the mixture starts to harden. The reaction occurs rapidly at first, depending on how finely the cement is ground and what admixtures are present. After its initial cure and strength are achieved, the concrete mixture continues to cure slowly over a longer period until it attains its final strength.

**Aggregate**: One of the basic components of concrete. Aggregate adds strength to the concrete and makes up 60 to 80 percent of the concrete's volume.

**Slag**: The ash produced during the reduction of iron ore to iron in a blast furnace.

**Curing**: The process that starts as soon as water is added to a concrete mixture. This process gives the concrete its hardness and strength.

#### Water Used with Concrete

Generally, any drinkable water (unless it is extremely hard or contains too many sulfates) may be used to make concrete. If the quality of the water is unknown or questionable, the water should be analyzed, or mortar cubes should be made and tested against control cubes made with drinkable water. If the water is satisfactory, the test cubes should show the same compressive strength as the control cubes after a 28-day cure time.

High concentrations of chlorides, sulfates, alkalis, salts, and other contaminants have corrosive effects on concrete and/or steel reinforcing bars, mesh, and cables. Sulfates can cause disintegration of concrete, while alkalis, sodium carbonate, and bicarbonates may affect the hardening times as well as the strength of concrete. The presence of these compounds in water mixed with concrete can also result in an effect called **efflorescence**, which occurs as concrete cures and moisture moves the compounds to the surface. The primary indication of efflorescence is a hard white film or layer on top of the concrete or surrounding surface. While efflorescence is not harmful to the concrete, it is unsightly, especially on painted or colored concrete or brick, as shown in *Figure 18*. It also indicates the presence of substances that may be harmful to reinforcing steel used in the concrete.

**Strength of Concrete**

The compression strength required for a specific concrete structure, such as a footing or slab, is normally specified on the construction drawings and/or specifications. Compression strength is expressed in pounds per square inch (psi).

**Efflorescence**: A deposit of compounds (salts) brought to the surface of concrete by moisture during the curing process. It typically appears as a white or light gray powdery substance on the surface of the concrete.

#### Admixtures for Concrete

Different types of concrete can be obtained by varying the basic materials and/or by adding other materials, called **admixtures**, to the mix. Admixtures are added to a concrete mixture before or during mixing to modify the characteristics of the final concrete. They may be used to improve workability during placement, increase strength, retard or accelerate strength development, increase frost resistance, and impart color. Usually, an admixture will affect more than one

**Admixtures**: Materials added to a concrete mix to change the concrete's properties. This could include retarding the setting time, reducing water requirements, and a variety of other properties.

### Spacing

The spacing between steel reinforcing bars must be taken into consideration when selecting the size of the coarse aggregate to use in a concrete mixture. If too large an aggregate is used when rebar is spaced closely, the aggregate may become jammed between the rebar and create a void in the concrete.

**Figure 18** Efflorescence on a concrete wall.
*Source:* Marbury/Shutterstock

characteristic of concrete. Therefore, its effect on all the properties of the concrete must be considered. Admixtures may increase or decrease the cost of concrete work by lowering cement requirements, changing the volume of the mixture, or lowering the cost of handling and placement.

Control of concrete setting time may reduce costs by decreasing waiting time for floor finishing and form removal. Extending the setting time may reduce costs by keeping the concrete plastic, thereby eliminating bulkheads and construction joints. In practice, it is desirable to fully pretest all admixtures with the specific concrete mix to be used, because the mix may affect the admixture efficiency and, ultimately, the final concrete.

### THINK ABOUT IT

### Concrete, Mortar, and Grout

What is the difference between concrete, mortar, and grout?

## 2.4.3 Mortar

A material closely related to concrete is mortar, which is also composed of concrete that uses an aggregate of fine sand, commonly referred to as *builder's sand*. In some instances, lime is also added to increase durability. Like other mixtures using cement, mortar begins curing (hardening) as soon as it is mixed with water. Cement in the mortar acts as the glue that holds concrete block, brick, rock, or other types of masonry together. Many types of mortars are designed for different applications, so it is important to select the mortar based on the masonry unit being used.

## 2.4.4 Grout

While mortar is used to hold or bind different types of masonry units together, grout is intended to flow and serve as a filler. As a result, grout uses more water than mortar. For example, the spaces between tile are filled with grout and allowed to harden. Grout is also available in many colors.

### Going Green

### Autoclaved Aerated Concrete

Autoclaved aerated concrete (AAC) is a lightweight precast building material cured under high pressure inside special ovens called autoclaves. AAC contains millions of very small bubbles that are generated during the manufacturing process, making the concrete extremely lightweight. AAC is a nontoxic material whose primary ingredient is fly ash. Fly ash is a recycled material that is generated by the electric utility industry. More than 50 million tons of fly ash are generated annually, making it plentiful for the production of AAC.

## 2.4.5 Concrete Masonry Unit Construction

Concrete masonry units (CMUs), also referred to as concrete block, are commonly used to build foundations and basement walls. Concrete block was once called cinder block because it contained the cinders left after burning coal.

Today, CMUs are manufactured under a more controlled environment using materials such as portland cement, sand, and gravel. After adding water to the portland cement, manufacturers add aggregates, such as sand and gravel, and admixtures to the mixture.

CMUs are machine-molded into shapes like the ones shown in *Figure 19.* They are compacted in the molds and cured, typically using live steam. After curing, the CMUs are dried and aged. The moisture content is checked; it must be a specified minimum amount before the blocks can be shipped for use.

### CMU Construction

CMUs are often used in commercial construction. In some parts of the country, they are also used for the walls of residential construction in place of wood framing. The CMUs can be painted on the outside or faced with brick, stucco, or other finish material.

### CMU Sizes

CMUs are available in a variety of sizes, with 8" CMUs being one of the most common sizes used for residential construction. The nominal dimensions of 8" CMUs are 8" × 8" × 16" (actual dimensions are 7⅝" × 7⅝" × 15⅝"). CMUs are available in modular sizes and colors determined by their ingredients. A variety of admixtures can give CMUs varied and attractive surfaces. Certain finishing techniques give CMUs the appearance of brick, rough stone, or cut stone. Like clay masonry units, CMUs can be placed in structural pattern bonds. *Figure 20* shows the names of the parts of a CMU.

CMUs take up more space than other building units (such as brick), so fewer are needed. CMU bed joints usually need mortar only on the shells and webs, so there is less mortaring as well.

### CMU Weights

CMUs are available in three weights: normal, lightweight, and aerated. Normal-weight CMUs can be manufactured with regular-, high-, and extra-high-strength concrete. CMUs using high- and extra-high-strength concrete are made with different aggregates and curing times, and are used to limit wall thickness in buildings over 10 floors high. Lightweight block is made with lightweight aggregates. The loadbearing and appearance qualities of normal and lightweight CMUs are similar; the major difference is that lightweight block is easier and faster to lay. Aerated block is made with an admixture that generates gas bubbles inside the concrete for a lighter block.

Common CMUs have two hollow cores, making it easy to reinforce CMU walls. Grout alone, or steel reinforcing bars combined with grout, is commonly used to fill the hollow cores. Reinforcement increases loadbearing strength, rigidity, and wind resistance.

Loadbearing CMUs are used as backing for veneer walls, bearing walls, and other structural uses. Both regular and specially shaped CMUs are used for paving, retaining walls, and slope protection. Nonstructural CMUs are used for screening, partition walls, and as a veneer wall for wood, steel, or other backing. Both kinds of CMUs are available in a variety of shapes and modular sizes.

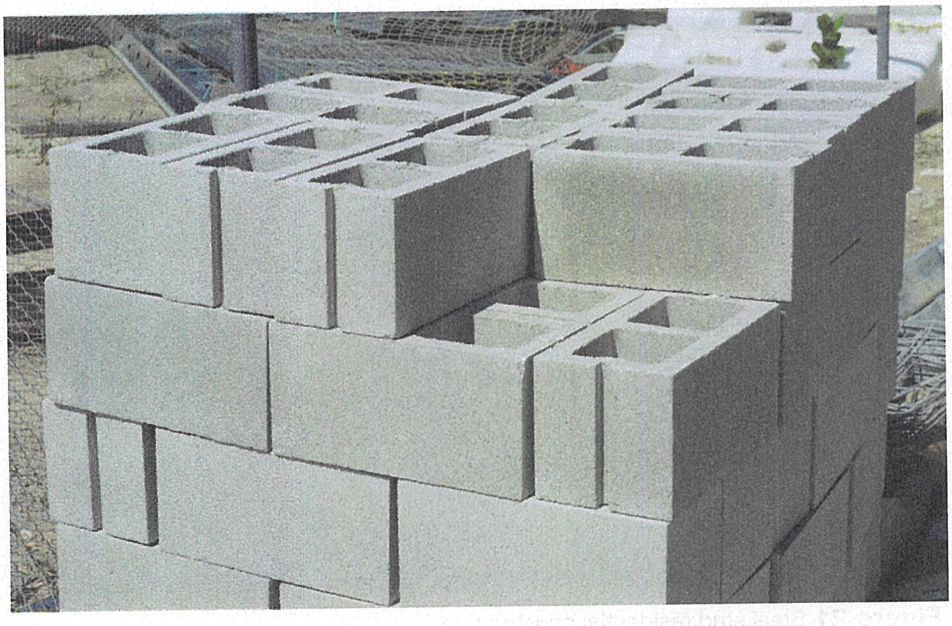


**Figure 19** Common concrete masonry units.

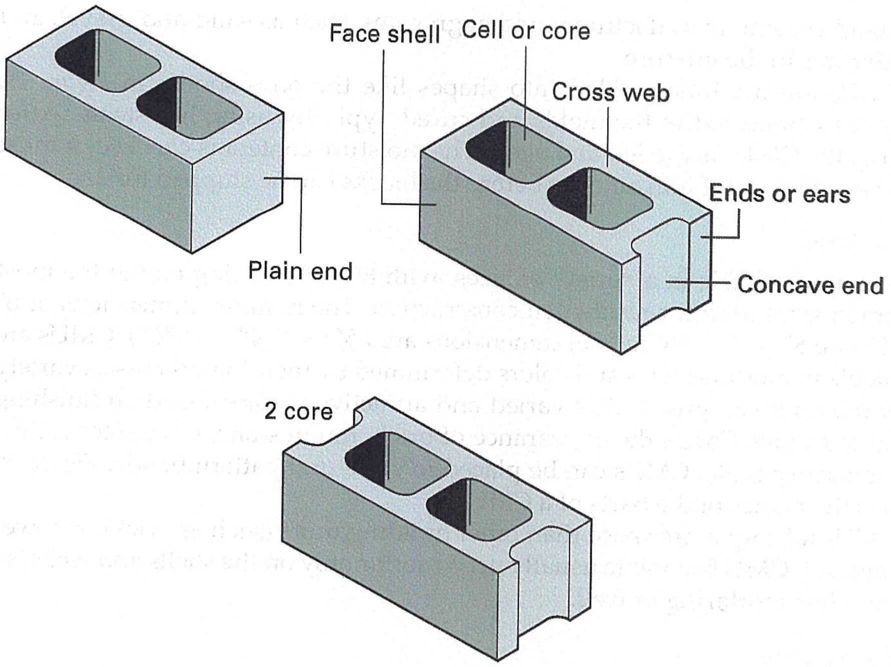


**Figure 20** Concrete masonry unit parts.

*Source:* The Brick Industry Association https://www.gobrick.com/home

## 2.5.0 Steel Framing Materials

Steel framing materials include light- and heavy-gauge framing members, such as steel studs (*Figure 21),* joists, and steel trusses.

### 2.5.1 Steel Framing

Steel framing offers many advantages including noncombustibility, dimensional uniformity, light weight, freedom from rot and moisture, and ease of construction. The steel framing components are manufactured to fit together easily. There are a variety of steel framing systems, both loadbearing and nonbearing types. Some nonbearing partitions are designed to be demountable or moveable and still meet the requirements of sound insulation and fire resistance when covered with the proper gypsum system.

### Identifying Light-Gauge Framing Members

The Steel Stud Manufacturers Association (SSMA) has developed an identification system that identifies the shape, web width, flange width, and steel thickness. This system, known as The Right S-T-U-F, provides the needed information in one location. S-T-U-F refers to the common light-gauge shapes:

S = studs or joists (C-shapes)
T = tracks
U = U-channels or channel studs (without lips)
F = furring channels

The web and flange widths are expressed in hundredths of an inch. The steel thickness is expressed in mils. For example, the identifier **400S125-33** on a steel framing member means the web width is 400, or 4" (400 ÷ 100 = 4"); the shape is S (stud); the flange width is 125, or $1\frac{1}{4}$" (125 ÷ 100); and the steel thickness is 33 mils, or 20 gauge.

**Figure 21** Steel stud residential construction.

## 2.5.2 Light-Gauge Framing

Light-gauge steel framing members are manufactured from 22- or 25-gauge sheet steel (the higher the gauge, the lighter the steel). Light-gauge steel framing members include C-shapes, tracks, U-channels, and furring channels. C-shapes are used as studs; tracks are used as top and bottom plates. These framing members may have a knurled or dimpled pattern along the exterior surface for positive screw settings. Light-gauge steel studs are available in a wide range of standard web widths ranging from 1⅝" to 6". The flanges are 1¼" deep, and the lip size varies by stud size (*Figure* 22.) Lengths of 6' to 16' are commercially available. Other lengths are available by special order.

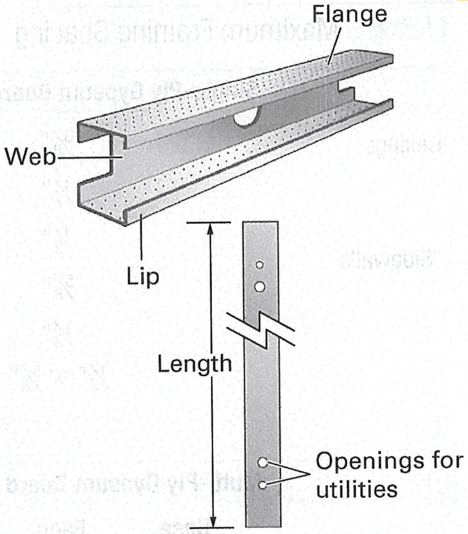


**Figure 22** Standard light-gauge steel stud.

## 2.5.3 Heavy-Gauge Framing

Heavy-gauge steel framing members are available in the same shapes as light-gauge framing members (*Figure* 23). These framing members are made from 20-gauge sheet steel and have knurled or dimpled sides for positive screw setting. Web and flange dimensions of heavy-gauge members are similar to those of light-gauge steel framing members. They also have cutouts and utility knockout holes 12" from each end and at the midpoint of the stud. Heavy-gauge studs can be ordered to the lengths that are needed.

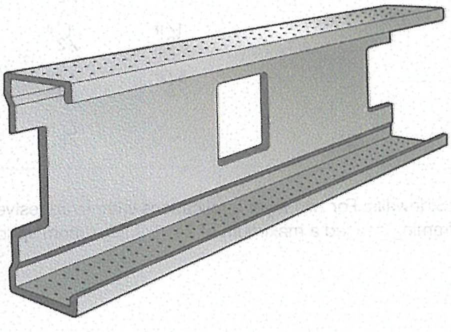


**Figure 23** Heavy-gauge steel stud.

Steel framing members are also available in thicknesses greater than 20 gauge. Steel studs are available in 18- 16-, 14-, 12-, and 10-gauge thicknesses, and are classified as structural steel studs. They are available in web widths of 2½" to 8" and flange widths of 2" or 2½". They can be ordered in whatever length is needed.

Although different materials are used, the general approach to framing with steel studs is the same as the approach used for wood studs. In fact, steel studs can be used with either wood plates or steel tracks. *Figure* 24 shows steel framing used in commercial construction.

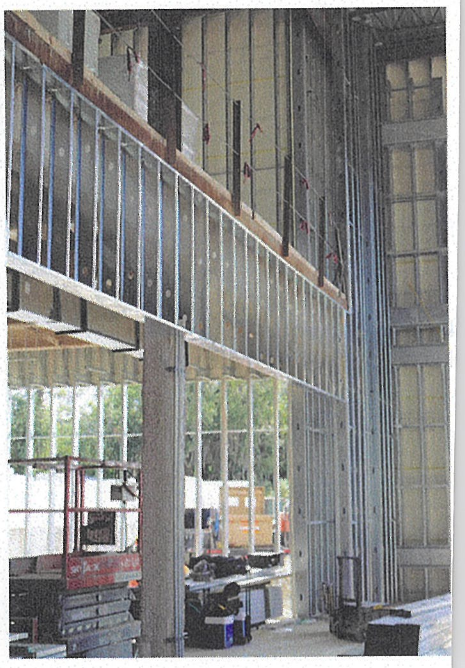


**Figure 24** Commercial steel framing.

Like wood framing, steel framing is installed 12", 16", or 24" on center (OC), openings are framed with headers and cripples, and special framing is needed for corners and partition Ts.

Depending on the load, reinforcement may be needed when framing openings. Walls also must be braced to keep them square and plumb until sheathing is applied. *Table* 5 shows the framing spacing for various gypsum board applications.

The erection of steel studs typically starts by laying steel tracks in position on the floor and ceiling and securing them. If the tracks are being fastened to concrete, a low-velocity powder-actuated fastener is generally used. If the tracks are being fastened to wood, such as in a residence, screws can be driven with a screw gun.

**WARNING!**

The use of a powder-actuated fastener requires special training and certification. The use of these tools may be prohibited by local codes because of safety concerns.

Once the tracks are in place, the studs and openings are laid out in the same manner as a wood frame wall. The studs may be secured to the tracks with screws, or they may be welded. In some cases, the entire wall will be laid out on the floor, then raised and secured. When heavy-gauge walls are used, they may be assembled and welded in a fabrication shop and brought to the site.

**TABLE 5** Maximum Framing Spacing

| | Single-Ply Gypsum Board Thickness | Application to Framing | Maximum OC Spacing of Framing |
|---|---|---|---|
| Ceilings | ⅜" | Perpendicular | 16" |
| | ½" | Perpendicular or parallel | 16" |
| *Sidewalls | ½" | Perpendicular | 24" |
| | ⅝" | Perpendicular | 24" |
| | ⅜" | Perpendicular or parallel | 16" |
| | ½" or ⅝" | Perpendicular or parallel | 24" |

**Fasteners Only—No Adhesive Between Piles**

| | Multi-Ply Gypsum Board Thicknesses | | Application to Framing | | Maximum OC Spacing of Framing |
|---|---|---|---|---|---|
| | Base | Face | Base | Face | |
| Ceilings | ⅜" | ⅜" | Perpendicular | Perpendicular | 16" |
| | ½" | ⅜" | Parallel | Perpendicular | 16" |
| | | ½" | Parallel | Perpendicular | 16" |
| | ½" | ½" | Perpendicular | Perpendicular | 24" |
| | ⅝" | ½" | Perpendicular | Perpendicular | 24" |
| | | ⅝" | Perpendicular | Perpendicular | 24" |

*Sidewalls: For two-layer applications with no adhesive between piles, ⅜", ½", or ⅝" gypsum board may be applied perpendicularly (horizontally) or parallel (vertically) on framing spaced a maximum of 24" OC. Maximum spacing should be 16" OC when ⅜" board is used as the face layer.

## 2.6.0 Calculate Framing and Concrete Quantities

For commercial construction projects, material quantities are typically calculated by an estimator and ordered to be delivered to the jobsite. For residential construction projects, a carpenter may need to calculate and order building materials and supplies. Therefore, an understanding of basic material quantities is needed to communicate the proper information to the lumber dealer or supply house.

### 2.6.1 Calculating Framing Materials

**Framing takeoff**: A basic count of framing lumber needed for a construction job.

Estimating quantities of basic construction materials often starts with determining how much framing material is needed for the job. This type of information is included on a **framing takeoff**, which may refer to the required studs for wall frames, horizontal plates for the top and bottom of the walls, and headers for door and window openings. Many framing takeoffs also list the number of paneling sheets needed for the job.

Start by referring to a set of approved drawings. If plans are unavailable, draw a rough outline of the wall(s) and include the overall length and height measurements of the walls, doors, and windows. Indicate on-center spacing between the studs (typically 16 inches) and mark on the drawings where walls intersect with other walls (corners).

#### Calculating Studs

To calculate the number of required studs, refer to *Figure 25*, then follow the steps below.

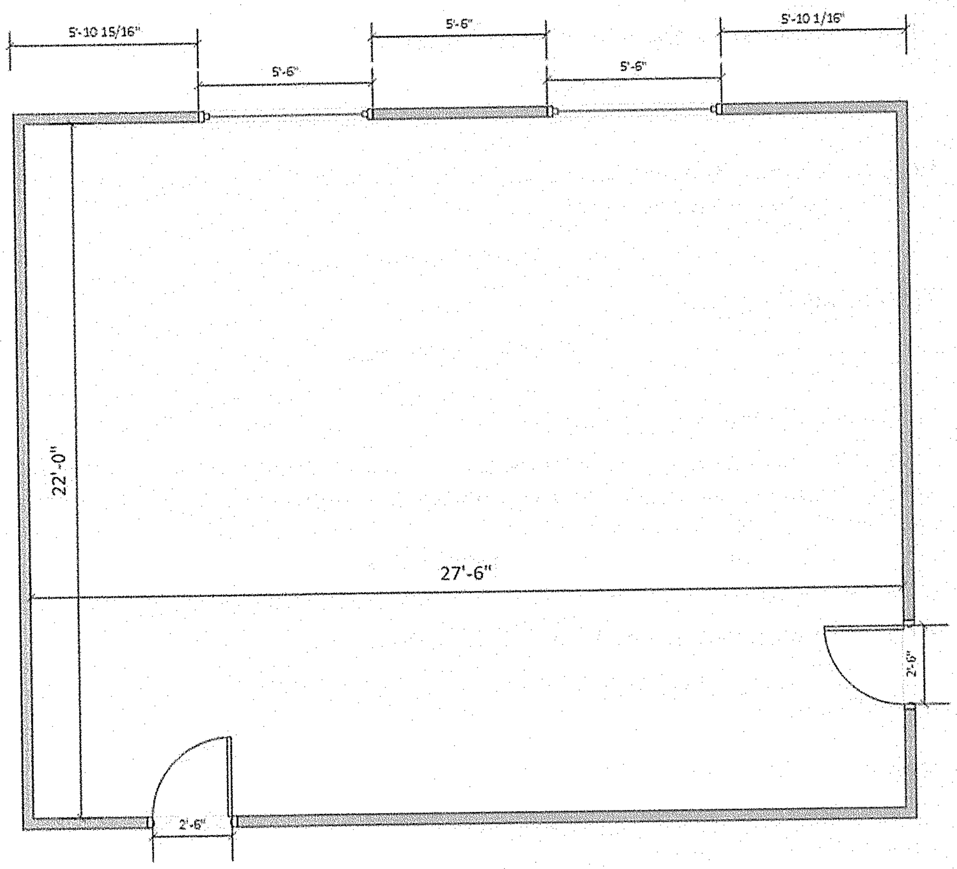


**Figure 25** Calculating framing materials.

**Step 1** Determine the total wall length in feet.

$$(22' \times 2) + (27.5' \times 2) = 44' + 55' = 99'$$

**Step 2** Multiply the total wall length by 0.75 (for 16-inch on center studs).

$$99' \times 0.75 = 74.25 \text{ (round up to 75)}$$

**Step 3** For each 90-degree corner, add 3 studs.

$$3 \times 4 = 12$$

**Step 4** For each 45-degree corner, add 4 studs.

(None in this example.)

**Step 5** For each wall intersection, add 2 studs.

(None in this example.)

**Step 6** For each wall opening 5 feet wide or less, add 2 studs.

$$\text{Two doors at } 2.5\,\text{ft each} = 2 \times 2 = 4$$

**Step 7** If wall openings are greater than 5 feet, add 4 studs for each opening.

$$\text{Two windows at } 5.5\,\text{ft each} = 4 \times 2 = 8$$

**Step 8** Add the numbers from Steps 2 through 7.

$$75 + 12 + 0 + 0 + 4 + 8 = 99$$

**Step 9** Multiply the total stud count by 0.10 to add 10% for waste, then round up to next whole number.

$$99 \times 0.10 = 9.9, \text{then round up to } 10$$

**Total Studs Required:**

$$99 + 10 = 109 \text{ studs}$$

### Estimating Bottom and Top Plates

Frames for load-bearing walls typically have a single bottom plate and two top plates. To calculate the linear feet required to build the plates, multiply the total length of the wall by 3, then add 10 percent for waste. Refer to *Figure 25* to estimate the linear feet for bottom and top plates.

**Step 1** Determine the total wall length in feet.

$$(22 \times 2) + (27.5 \times 2) = 44 + 55 = 99'$$

**Step 2** Multiply the total wall length by 3.

$$99' \times 3 = 297'$$

**Step 3** Add 10 percent for waste to the total length from Step 2, then round up to the nearest whole number.

$$297' \times 0.10 = 29.7'$$

$297' + 29.7' = 326.7'$ rounded up $= 327'$ linear feet required for bottom and top plates.

### Header Calculations

Headers span the top of the opening for windows and doors. They are frequently built using two pieces of 2" × 12" sawn lumber. However, check the approved construction documents for header size. When fastened together, the header is 3" thick. Often, a ½" wood structural panel is sandwiched between the two 2 × 12 members to create a header that measures 3½", which matches the thickness of the 2 × 4 wall. To estimate the header framing materials, measure the width of the opening, and then add 7 inches. To calculate the total length of headers needed for the windows shown in *Figure 25*, follow the steps below:

**Step 1** Add 7" to the width of the window opening to account for the number of jack studs required for bearing under each end of the header. Longer headers might require additional jack studs.

$$5'\text{-}6'' + 7'' = 73'' \times 2 \text{ windows} = 146''$$

**Step 2** Multiply the total length in Step 1 by 2 (two-board thickness of header).

$$146'' \times 2 = 292''$$

**Step 3** To calculate the linear feet needed for headers, divide the total from Step 2 by 12 and round up to the nearest whole number.

$$292'' \div 12 = 24.33' \text{ rounded up to } 25'$$

**NOTE**

You should be able to determine whether two 12"-long 2 × 12 members would be sufficient for these two headers, depending on the number of jack studs required. When developing an estimate, think about common available lumber lengths, including 8', 10', 12', and 16' lengths.

### Wood Structural Panel Calculations

In many areas, exterior walls are fully sheathed with wood structural panels such as OSB. Assuming 8′ wall heights for *Figure 25*, follow these steps to calculate the required number of 4′ × 8′ sheets of wood structural panels:

**Step 1** Determine the total wall length in feet.

$$(22' \times 2) + (27.5' \times 2) = 44' + 55' = 99'$$

**Step 2** Divide total wall length by 4 and round up.

$$99' \div 4 = 24.75 \text{ or } 25 \text{ sheets}$$

Another way of calculating the needed number of panels is to determine the overall area to be covered. The **area** of a floor or roof can be calculated by multiplying its length and width (length × width = area). Once you have calculated the total area, it can be divided by a panel's area to determine the number of required panels. Use the following formula to calculate the number of needed panels:

**Area:** The surface or amount of space occupied by a two-dimensional object such as a rectangle, circle, or square.

$$\begin{aligned}&\text{Number of panels} =\\&\text{Floor or roof area (length} \times \text{width [in feet])}\\&\div \text{panel area (length} \times \text{width [in feet])}\end{aligned}$$

For example, to determine the number of 4′ × 8′ panels needed for the room shown in *Figure 25*, use the following steps:

**Step 1** Determine the area of the roof.

$$\text{Roof area} = 27.5' \times 22' = 605 \text{ square feet}$$

**Step 2** Determine the area of a panel.

$$\text{Panel area} = 4' \times 8' = 32 \text{ square feet}$$

**Step 3** Determine the number of needed panels by dividing the roof area by the panel area, and then rounding up.

$$\text{Number of panels} = 605 \div 32 = 18.9 \text{ (rounded up} = 19 \text{ panels)}$$

**NOTE**

There will be excess based on your window and door opening areas. If there are a lot of windows and doors, take the time to fine tune your estimate.

### Trim and Moldings

Trim and moldings are priced by the lineal foot and are ordered by the dimension of the piece (for example, 150' of 1" quarter round molding). *Appendix C* contains lumber conversion tables.

## 2.6.2 Estimating Concrete Volume

Concrete work requires accurate measuring and estimating of concrete quantities. Fortunately, most concrete structures can be divided into rectangular or circular shapes. These shapes are individually estimated and the results are added together to obtain the required **volume** of concrete. For instance, a floor is a rectangular horizontal slab. A footing and a foundation wall can be divided into a long rectangular shape representing the footing and a vertical slab representing the wall. The volume of each can be calculated and the results added together for the total volume. Construction drawings for a project will provide the dimensions for the various portions of a concrete structure, and these dimensions are used to calculate the volume of concrete required for the structure. For reference purposes, *Appendix E* provides area or volume formulas

**Volume:** The amount of space occupied in three dimensions (length, width, and height).

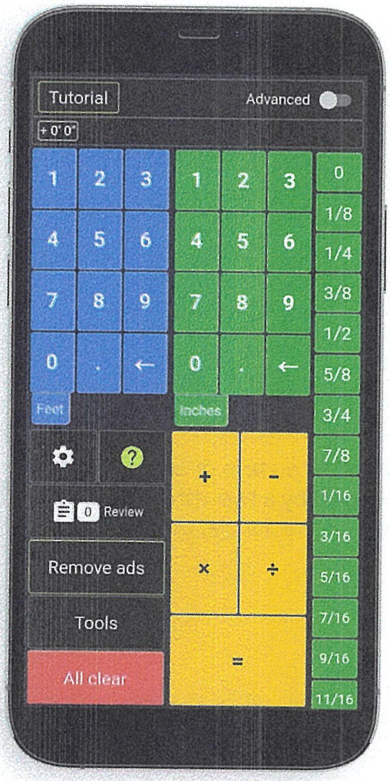


**Figure 26** Smartphone with construction calculator app.

for various geometric shapes and a table for conversion of inches to fractions of a foot or a decimal equivalent.

### 2.6.3 Rectangular Volume Calculations

Several methods can be used to determine the volume of concrete required for a rectangular object. One method uses the following formula:

$$\text{Cubic yards of concrete (rounded up to next } \tfrac{1}{4} \text{ yard)} = \frac{\text{Thickness (in feet)} \times \text{width or height (in feet)} \times \text{length (in feet)}}{27 \text{ (cubic feet/cubic yard)}}$$

To use the formula, all dimensions in inches must be converted to feet and/or fractions of a foot and then into a decimal equivalent. For example:

$$7'' = \left(\tfrac{7}{12}\right)' \text{ or } (7 \div 12)' = 0.58'$$
$$8'' = \left(\tfrac{8}{12}\right)' \text{ or } (8 \div 12)' = 0.66'$$
$$23'' = \left(\tfrac{23}{12}\right)' \text{ or } (23 \div 12)' = 1.92'$$

The other two methods involve knowing the width or height and length of an area in feet, along with the thickness in inches, and then using a construction calculator, smartphone with a construction calculator (*Figure 26*) or a concrete table (*Figure 27*) and a simple formula to determine the volume.

### 2.6.4 Example Calculation Using the Formula

Using the calculation formula, determine the amount of concrete required for the partial wall, footing, and floor slab plan shown in *Figure 28*.

**Step 1** The entire footing and wall length must be determined. Because the wall is centered on the footing, the wall length is the same as the footing length:

$$\text{Footing length} = \text{wall length} = 20' + (15 - 2)' = 33'$$

**Step 2** Determine the floor slab length and width:

$$\text{Length} = 20' - 16'' = 20' - 1.33' = 18.67'$$
$$\text{Width} = 15' - 16'' = 15' - 1.33' = 13.67'$$

**Step 3** Using the formula, determine the volume of the wall, footing, and slab:

$$\text{Volume} = \frac{\text{width or height (feet)} \times \text{length (feet)} \times \text{thickness (feet)}}{27 \text{ (cubic feet/cubic yard)}}$$

$$\text{Wall} = \frac{3 \times 33 \times 0.67}{27} = \frac{66.33}{27} = 2.46 \text{ cubic yards}$$

$$\text{Footing} = \frac{2 \times 33 \times 0.67}{27} = \frac{44.22}{27} = 1.64 \text{ cubic yards}$$

$$\text{Slab} = \frac{13.67 \times 18.67 \times 0.5}{27} = \frac{127.6}{27} = 4.73 \text{ cubic yards}$$

| ONE CUBIC YARD OF CONCRETE WILL PLACE: | | | |
|---|---|---|---|
| THICKNESS | SQ FT | THICKNESS | SQ FT |
| 1" | 324 | 7" | 46 |
| 1¼" | 259 | 7¼" | 45 |
| 1½" | 216 | 7½" | 43 |
| 1¾" | 185 | 7¾" | 42 |
| 2" | 162 | 8" | 40 |
| 2¼" | 144 | 8¼" | 39 |
| 2½" | 130 | 8½" | 38 |
| 2¾" | 118 | 8¾" | 37 |
| 3" | 108 | 9" | 36 |
| 3¼" | 100 | 9¼" | 35 |
| 3½" | 93 | 9½" | 34 |
| 3¾" | 86 | 9¾" | 33 |
| 4" | 81 | 10" | 32.5 |
| 4¼" | 76 | 10¼" | 31.5 |
| 4½" | 72 | 10½" | 31 |
| 4¾" | 68 | 10¾" | 30 |
| 5" | 65 | 11" | 29.5 |
| 5¼" | 62 | 11¼" | 29 |
| 5½" | 59 | 11½" | 28 |
| 5¾" | 56 | 11¾" | 27.5 |
| 6" | 54 | 12" | 27 |
| 6¼" | 52 | 15" | 21.5 |
| 6½" | 50 | 18" | 18 |
| 6¾" | 48 | 24" | 13.5 |

**Figure 27** Portion of typical concrete table.

**Step 4** Add the wall, footing, and slab volumes:

$$2.46 + 1.64 + 4.73 = 8.83 \text{ rounded up to 9 cubic yards}$$

For the plan shown, 9 cubic yards of concrete will be required.

### 2.6.5 Cylindrical Volume Calculations

The volume of concrete required for a circular column or pier can be calculated by using the following formula:

$$\text{Cubic yards of concrete} = \frac{\pi \times \text{radius}^2 \text{ (in square feet)} \times \text{height (in feet)}}{27 \text{ (cubic feet/cubic yard)}}$$

*Where:*

- $\pi = 3.14$
- Radius = diameter (in feet) of column ÷ 2
- Measurements in inches are converted to feet

As with rectangular volume calculations, a certain percentage of waste must be added to the circular volume estimate based on the jobsite conditions.

**Calculating the Volume of Concrete**

When using any of the three methods for calculating the volume of concrete needed for a job, a waste factor must be taken into consideration. Typically, about 5 percent of the calculated volume is added to account for waste. For larger jobs, experienced carpenters order the required number of full truckloads (typically 12 cubic yards per load), and then specify the required amount needed for the last truckload once the total volume of concrete needed is known.

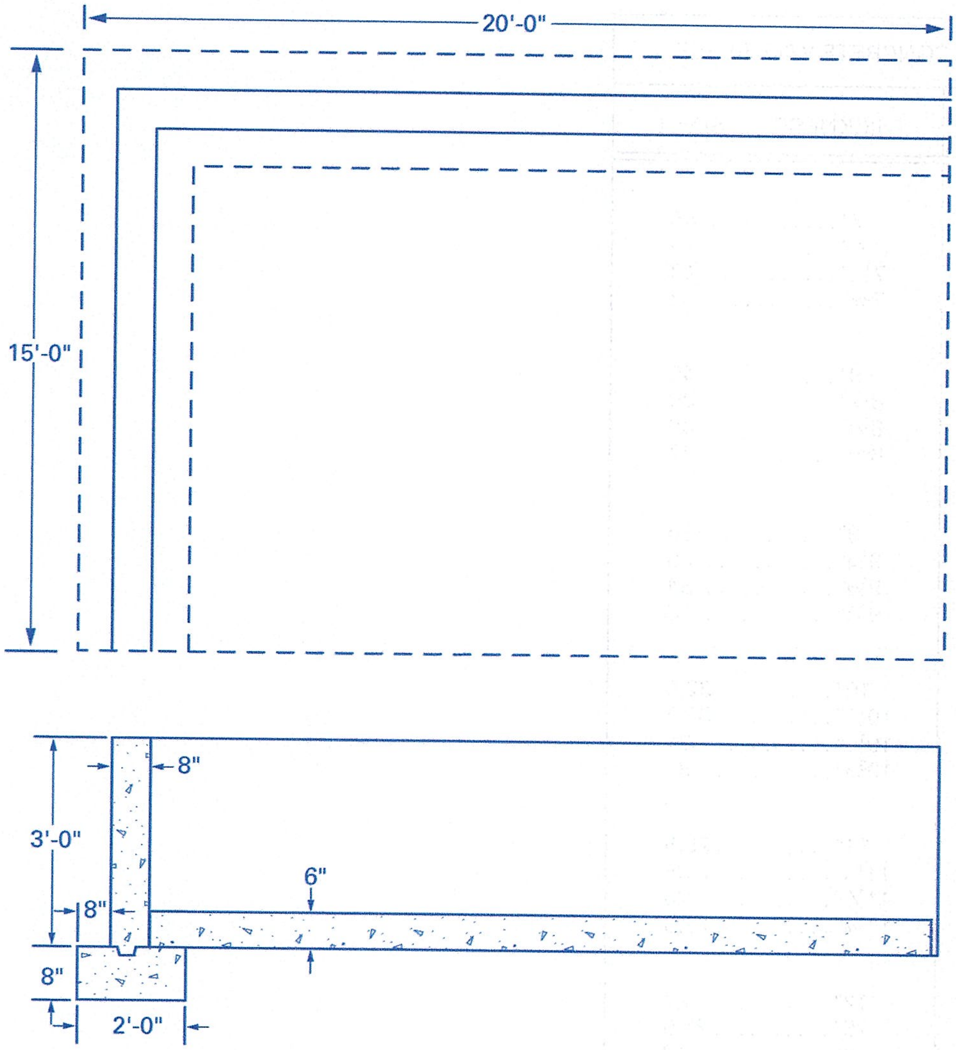


**Figure 28** Partial wall, footing, and floor slab plan.

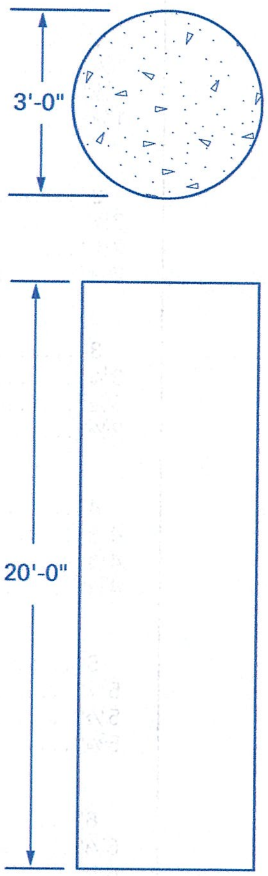


**Figure 29** Typical circular column plan.

### Measure Twice, Cut Once

An apprentice carpenter was helping his boss remodel a basement. The boss asked the apprentice to measure and cut the studs for the walls. The apprentice, looking to impress the boss, attacked the job with gusto. Instead of cutting and checking the fit of the first stud, he cut all of them at once, based on a quick measurement. When all the studs were cut, they started to place them, only to find out that each stud was $3\frac{1}{4}$" short. The apprentice had forgotten to add the measuring tape case to the tape reading.

### 2.6.6 Example Calculation of Cylindrical Volume

Using the circular volume formula, determine the volume of concrete required for the circular column shown in *Figure 29.*

---

**Step 1** Determine the radius of the column:

$$3' \div 2 = 1.5'$$

---

**Step 2** Calculate the volume using the formula:

$$\text{Cubic yards of concrete} = \frac{\pi \times \text{radius}^2 \text{ (in square feet)} \times \text{height (in feet)}}{27 \text{ (cubic feet/cubic yard)}}$$

$= 5.23$ cubic yards rounded up to $5\frac{1}{4}$ cubic yards

For the plan shown, $5\frac{1}{4}$ cubic yards of concrete will be required.

## 2.0.0 Section Review

1. Which of the following defects do *not* occur naturally in wood?
   a. Shakes
   b. Torn grain
   c. Cups
   d. Splits

2. The lumber that comes from the sawmill prior to any dressing or planing is called _____.
   a. dimension lumber
   b. matched
   c. rough
   d. stressed

3. Preservative-treated lumber is commonly used to build _____.
   a. sill plates
   b. roof joists
   c. floor trusses
   d. cabinets

4. Engineered wood products are as strong and dimensionally stable as similar solid wood products.
   a. True
   b. False

5. The basic materials used to make concrete are _____.
   a. portland cement, rocks, admixture
   b. portland cement, aggregates, water
   c. portland cement, water, grout
   d. portland cement, mortar, water

6. An example of light-gauge steel framing is _____.
   a. 10-gauge sheet steel
   b. 15-gauge sheet steel
   c. 20-gauge sheet steel
   d. 25-gauge sheet steel

7. Multiply the length by the width to determine the _____.
   a. area
   b. volume
   c. diameter
   d. total board feet

# 3.0.0 Handling and Storing Building Materials

## Performance Tasks

There are no performance tasks in this section.

## Objective

Explain how to properly handle and store building materials.

a. Describe how to safely handle and store wood, concrete, and steel building materials.

Building materials are often delivered to a jobsite days or weeks before they are used. Unless the lumber, plywood, and other building materials are properly handled and stored, they can be seriously damaged. Although a contractor allows for a certain amount of waste and spoilage in an estimate, such an allowance does not account for damage due to improper storage. It is up to the work crew to take care of the building materials.

## 3.1.0 Material-Handling and Storage Basics

To reduce the risk of injury when manually handling material, plan your task before doing it, wear the appropriate personal protective equipment (PPE), and follow proper lifting procedures. Be aware of hazards when working from heights or working near suspended loads.

### 3.1.1 Pre-Task Planning

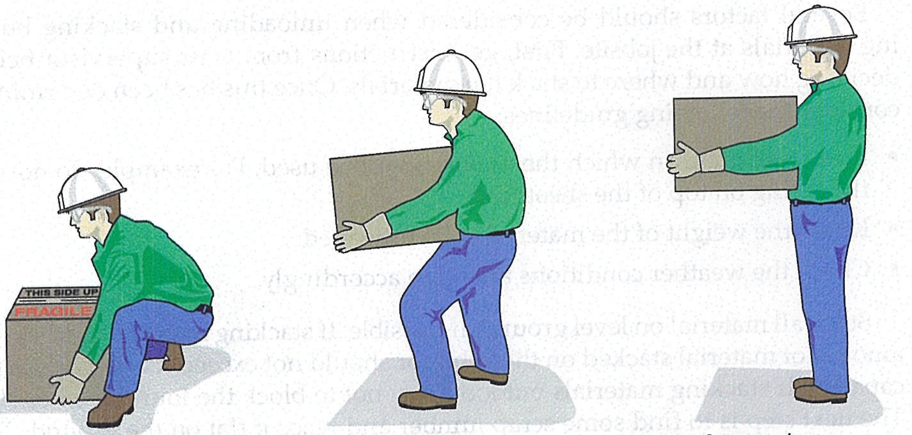
Most material-handling accidents occur when workers are new and relatively inexperienced at a job, or when experienced workers think that accidents cannot happen to them. Before handling any material, think about what you are doing. Always assess the situation before attempting to lift any material by doing the following:

- Check to make sure the load is not too big, too heavy, or hard to grasp.
- Make sure the load does not have protruding nails, wires, or sharp edges.
- Make sure the material is something you are able to lift by yourself. If not, ask a coworker for assistance.
- Inspect your path of travel. Look out for hazards that could result in a slip, trip, or fall. If there are hazards in your path of travel, move them, or go around them.
- Always read the warning labels or instructions on materials before moving them, and be aware of the potential dangers if you mishandle a particular product.

### 3.1.2 Personal Protective Equipment

It is important to wear the proper clothing and PPE when moving or handling materials. Remember the following safety guidelines when dressing to perform materials-handling operations:

- Do not wear loose clothing that can get caught in moving parts.
- Be sure to button shirt sleeves and tuck in shirt tails.
- Remove all rings and jewelry.
- Tie back and secure long hair underneath your hard hat.
- If a wristwatch is worn, wear one that will easily break away if it gets caught in machinery.
- Wear gloves whenever cuts, splinters, blisters, or other hand injuries are possible. Select gloves that fit properly. Tight gloves may increase hand fatigue. Loose gloves reduce grip strength and may get caught on moving objects or machinery.
- Gloves should be removed when working with rotating machinery and equipment with exposed moving parts.



Bend your knees and grasp the object firmly.

Lift the object by straightening your legs.

Move forward once you are in full vertical position.

**Figure 30** Proper lifting technique.

### 3.1.3 Proper Lifting Procedures

It is important to use proper lifting techniques to reduce the risk of back injuries. Apply the following rules when lifting or moving construction materials:

- Determine the weight of the load prior to lifting, then plan your lift.
- Know where it is to be unloaded and remove any slipping or tripping hazards from your path of travel.
- Know your limits and what you are able to physically handle when lifting a load.
- If you believe the load is too heavy, ask a coworker for help.

When preparing to lift an object, make sure you have a firm footing. Bend your knees and get a good grip. Be sure to lift with your legs, keeping your back straight, and your head up. Face in the planned direction of travel and then lift. To avoid musculoskeletal injury, avoid twisting until you are standing straight, and then proceed in the direction of travel. Keep the load close to your body (*Figure 30*) while moving.

When unloading materials, use your leg muscles to set them down. Space your feet far enough apart to maintain good balance and control of the object. When placing the load down, move your fingers out of the way to avoid pinching or crushing them.

### 3.1.4 Storing Wood Products

When a complete framing package for a residence is delivered to the jobsite, the framing package looks great. All the material is neatly packed. Some material is strapped and some neatly tied. When the load is dumped, however, it may shift. A neat load can quickly become a pile of lumber spread in different directions. In some cases, lumber may be split or broken while other materials may be partially buried in sand, mud, or snow. If the framing is left in this condition, one of more of the following may result:

- The lumber will be exposed to the elements. Sun, wind, rain, and snow can create serious problems.
- The lumber may become warped, cupped, or crooked.
- Some lumber may crack or split when strain is placed against it.
- The contractor may have to pay to replace damaged materials.
- Time needed to replace the damaged materials may affect the project schedule.
- There may be a safety hazard associated with using damaged materials.

A simple way to avoid these problems is to have knowledgeable workers at the site when the materials are delivered. A few hours spent stacking the lumber and protecting it from the elements can save your employer the cost of replacing damaged materials. Also, delivery crews are more likely to be careful when an observer is present.

### Damaged or Defective Lumber

When lumber is properly stored at a jobsite, most of it will likely be usable. In some situations, however, the lumber may be too damaged to use, at least for its intended purpose. Experienced carpenters can find other uses for damaged and defective lumber. Wood with defects like knots may be desirable for roughing-in. Some warped lumber can be used in joists and rafters if the proper precautions are taken to account for the distortion. Consult with an experienced carpenter or supervisor when you encounter these types of situations.

Several factors should be considered when unloading and stacking building materials at the jobsite. First, get instructions from your supervisor before deciding how and where to stack the materials. Once this has been determined, consider the following guidelines:

- Know the order in which the material will be used. For example, do not put the siding on top of the sheathing.
- Know the weight of the material to be unloaded.
- Check the weather conditions and plan accordingly.

Stack all material on level ground, if possible. If stacking material indoors, the amount of material stacked on the subfloor should not exceed its weightbearing capacity. If stacking materials outdoors, try not to block the foundation or slab. The next step is to find some scrap lumber and place it flat on the ground. Two or three 2 × 4s spaced approximately 4' apart from each other will work nicely. Stack the widest lumber on top of this scrap lumber. Be sure the good lumber does not come in contact with the ground. Ensure that there is enough support under the lumber so that it will not sag.

Separate the lumber, keeping the treated material from the regular material.

Keep your materials banded until it is time to use them. Try to avoid using lumber that has been exposed to heavy rain.

Protect the lumber from the elements by covering the materials with a waterproof material (e.g., roofing paper or polyethylene). Cover the lumber to protect it from the elements, but not to prevent air from circulating around the stack. Preventing air circulation could cause twisting or warping, depending on the moisture content of the air.

Special care is needed for interior finish materials. If you are using knockdown (KD) door frames (either wood or metal) for the doors, these usually come tied together. Always ensure that the door frames (also known as jambs) are stacked flat and off the floor or concrete. Some moldings will come wrapped or tied. Take care to lay them flat and off the floor or concrete. Wall paneling should be treated the same way. Extreme caution should be taken not to damage the edges or mar the face of the panel.

Stacking interior finish materials on top of scrap lumber serves two purposes:

1. It prevents moisture in the concrete floor from coming in contact with the bottom piece.
2. It protects the materials from flowing water. Although the finish material is under cover, a burst pipe is always a possibility.

### 3.1.5 Wood Structural Panel Storage

Remember, when stacking wood structural panels, only two methods may be used:

- Sheets may be stacked flat on a solid surface and off the floor or ground (*Figure 31*).
- Sheets may be stacked in a full vertical position between two posts. Keep the panels off the floor or ground. Storing panels at an angle will cause the material to warp or twist.

### 3.1.6 I-Joist Storage and Handling

Like all engineered wood products, I-joists can be damaged if not stored properly. They can also cause injury if they are not moved or handled properly. Use the following guidelines when storing or handling I-joists:

- Store I-joists vertically, oriented the way they would be installed.
- Cover I-joists so no water or rain exposure. This is especially important when storing on the jobsite.
- Store I-joists on well-drained ground at least 6" off the ground with supports no more than 8' apart.

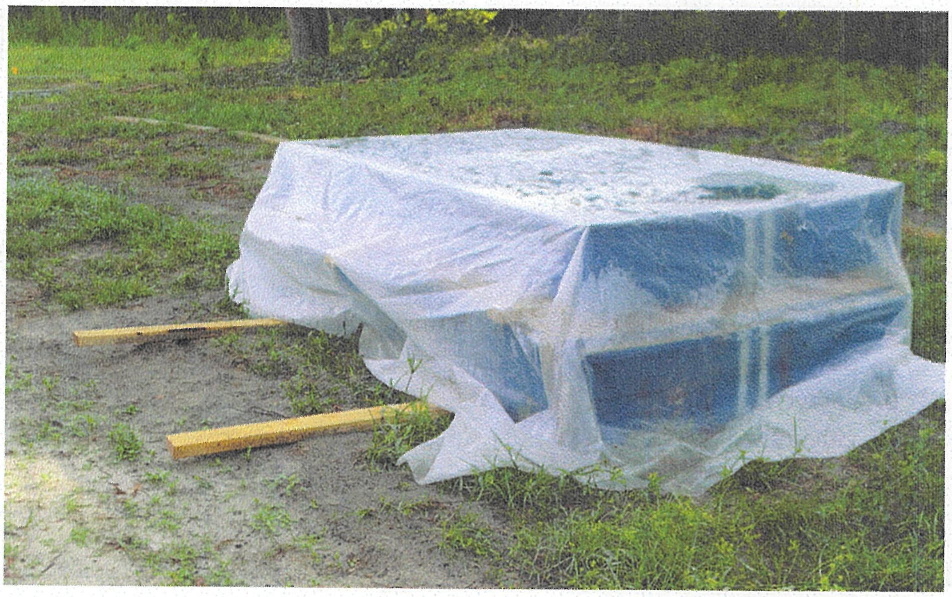


**Figure 31** Storing wood structural panels.

- Do not walk on or stack other building materials on top of I-joists. Only walk on I-joists after they have been installed.
- Do not twist I-joists when storing or transporting.
- Open wrapped I-joists only after getting on site and preparing to install.

### 3.1.7 Storing Concrete Products

Portland cement is a moisture-sensitive material. For smaller quantities, portland cement is commonly available in paper bags that hold one cubic foot of cement by volume and weigh 94 pounds. Portland cement can be stored indefinitely in dry conditions. Bags of cement should always be stored off the ground and in a dry location to prevent the cement from absorbing moisture that causes lumps to form in the cement powder. The bags should be stacked closely together to reduce air circulation. If bagged portland cement is stored outdoors, it should be stacked on pallets and covered with a waterproof covering. For larger concrete quantities, portland cement is provided in bulk and should be stored in watertight bins or silos.

### 3.1.8 Storing Steel Products

Steel framing members should be handled carefully because the edges of the members may be sharp. The members should be stored in a dry location and/or covered to ensure moisture does not affect them. Light-gauge framing members typically receive a **galvanized** coating to prevent corrosion. However, if the coating is deeply scratched, corrosion may occur, which will weaken the framing member.

**Galvanized:** Protected from corrosion (rust) by a zinc coating.

## 3.0.0 Section Review

1. When unloading materials, use your _____.
   a. leg muscles
   b. upper back muscles
   c. neck muscles
   d. lower back muscles

2. To prevent corrosion, light-gauge steel framing members are typically _____.
   a. painted
   b. sprayed
   c. galvanized
   d. dyed

## 4.0.0 Fasteners, Anchors, and Adhesives

### Performance Task

3. Demonstrate safe and proper installation of various types of fasteners, anchors, and adhesives.

### Objective

Identify fasteners, anchors, and adhesives used in construction.

a. Describe different types of nails, screws, bolts, and staples.
b. Summarize the categories of mechanical anchors.
c. List adhesives used in construction and identify their applications.

Various types of fasteners, anchors, and adhesives are used to fasten materials together temporarily or permanently. The project specifications and construction drawings contain information regarding the type of fastener, anchor, or adhesive to use in a given situation.

## 4.1.0 Nonthreaded and Threaded Fasteners

There are many types and sizes of threaded and nonthreaded fasteners and each is designed for a specific application. Failure of fasteners can result in a number of different problems. To perform quality work, it is important to use the correct type and size of fastener for the specified job. It is also important to properly install the fastener.

### 4.1.1 Nails

Nailing is a common method used for attaching two pieces of lumber. Some nails are made specifically to be driven with a hammer; others are made for use with power-driven nailers. Nails are often referred to as 8-**penny**, 10-penny, etc. This method of designating nail length dates back many years. In written form, the penny designation appears as a lowercase d (*Figure 32*); an 8-penny nail would read 8d, and so forth. Nails longer than 16d are commonly referred to as spikes. Spikes range from 20d (4") to 60d (6"). The thickness (gauge) of the nail shank increases as the length increases.

**Penny**: A designation of nail diameter and length; commonly abbreviated with the letter d.

#### Types of Nails

Many types of nails are available (*Figure 33*), each with specific applications as follows:

- *Common nails*—Common nails are the most frequently used of all nails. They have a flat head, smooth and round shank (shaft), and diamond point. They are available from 2d to 60d in length. Common nails are used when appearance is not of prime importance, such as in rough framing or building concrete forms.
- *Box nails*—Box nails are very similar to common nails in appearance, except they have a thinner head and shank and have less of a tendency to split the wood. They

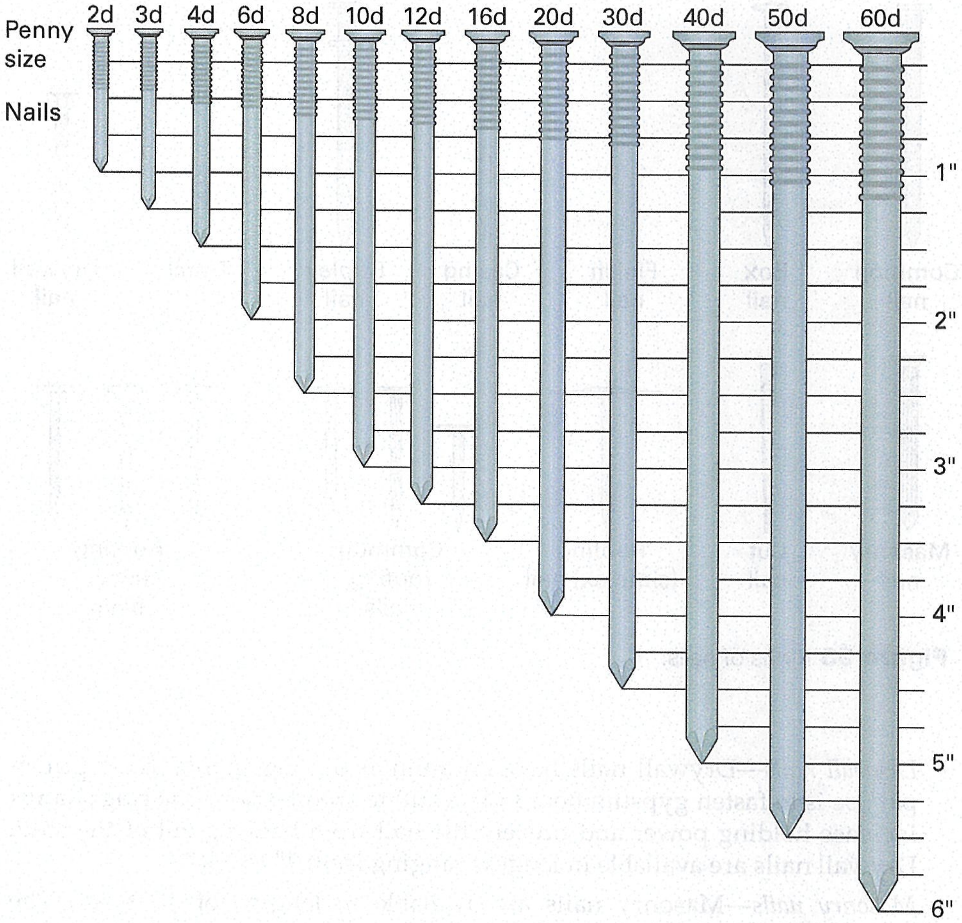


**Figure 32** Nail sizes.

often have a resin coating to resist rust and create more holding power. Box nails are available from 2d to 40d.

- *Finish nails*—Finish nails have a small barrel-shaped head with a slight indentation in the top to receive a **nail set**, so the nail head can be driven slightly below the surface of the wood. The void above the head is then filled with a putty or filler before paint or finish is applied to conceal the nail. Finish nails are used for installing millwork and trim where the final appearance is important. Their small heads reduce their holding power considerably. If holding power is important, finish nails can be obtained with galvanized coatings.
- *Casing nails*—Casing nails look a lot like finish nails; however, they have a conical-shaped head and the shank is larger. In addition, casing nails are available in lengths from 2d to 40d (as opposed to the 20d maximum length of a finish nail). Casing nails have more holding power because of the larger shank and the shape of the head.
- *Duplex or double-headed nail*—Duplex nails are designed for building concrete forms and other temporary work that will later be disassembled. The advantage of duplex nails is that they can be driven to the first head, which gives them sufficient holding power. They can be easily removed later with a claw hammer or wrecking bar.
- *T-nails*—T-nails are specially designed nails used in pneumatic nailers. They are coated with resin and available in strips for insertion into the nailer. T-nails are available in lengths of 1¼", 1½", 1¾", 2", 2⅜", and 2½". These nails are also available with galvanized coatings. The use of a pneumatic nailer reduces installation time as it only takes a pull of the trigger to drive them home.
- *Cement-coated nails*—Cement-coated nails are coated with an adhesive (cement) to provide greater holding power. As the nails are driven, the coating melts due to the friction created when driving the nails. The coating then hardens when it cools, creating an excellent bond with the base material.

**Nail set**: A punch-like tool used to recess finish nails.

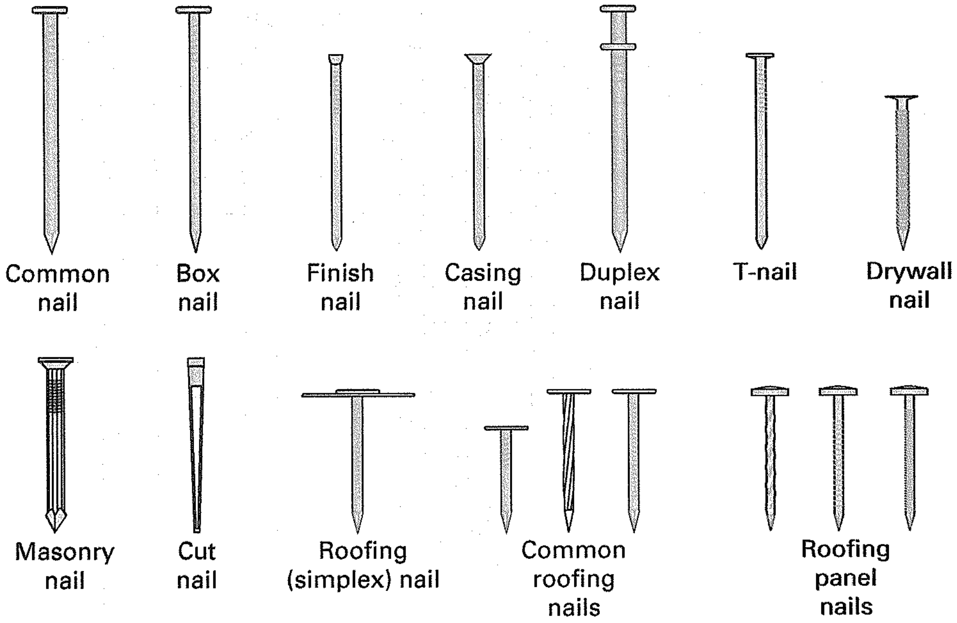


**Figure 33** Kinds of nails.

- *Drywall nails*—Drywall nails have an annular or ring shank. Their principal use is to fasten gypsum board (drywall) to wood studs. The ring shanks increase holding power and prevent the nail from backing out of the stud. Drywall nails are available in lengths ranging from 1" to 2½".
- *Masonry nails*—Masonry nails are available in lengths of ½" to 4". The shanks on longer masonry nails are grooved, and the nails have a sinker head. Masonry nails are case-hardened and are used to fasten metal or wood to masonry or concrete.
- *Cut nails*—Cut nails could also be grouped in with masonry nails, because in today's construction they are seldom used for other than masonry purposes. Cut nails are rectangular in cross section, have a blunt point, and have little tendency to bend. They are available in lengths up to about 5″ long.
- *Powder-actuated fasteners*—These fasteners come in a variety of shapes and sizes. All these fasteners are designed to be driven by powder-actuated tools, which are used to drive fasteners into concrete, steel, masonry, and wood. They are commonly used to attach steel studs and plates to concrete.
- *Roofing nails*—Most roofing nails are galvanized to resist rusting. There are several types of roofing nails:
  - Common roofing nails are available in lengths of ¾" to 2". These roofing nails have a thin head but different types of shanks. Common roofing nails are primarily used to fasten asphalt or fiberglass shingles to roof sheathing. They are also used to fasten insulation board to studs. Longer roofing nails are used for re-roofing jobs, while shorter ones are used on new roofs.
  - Roofing panel nails have a neoprene washer. They range in length from 1¾" to 2½", with either a helical (spiral) or plain shank. The helical shank has greater holding power. Roofing panel nails are used on fiberglass, steel, or aluminum roofing panels. The neoprene washer serves as a weatherproofing seal.

The following are some additional types of nails that may be encountered:

- *Hardboard siding nails*—These nails are designed for installing aluminum, vinyl, and steel siding.
- *Insulated siding nails*—These nails have a zinc coating and are available in various colors to match the color of the siding being installed.

- *Panel nails*—These nails are also available in various colors and have a plain- or ring-shank design. The head is small and blends in with the paneling for a good appearance.
- *Wire brads*—Wire brads look similar to regular finish nails. However, they have smaller shanks than finish nails, thus reducing splitting tendencies. Wire brads are used for fine finish work and are available in lengths from $\frac{3}{16}$" to 3".
- *Escutcheon pins*—Escutcheon pins are specially designed nails, which generally come as part of a hardware kit. They have an oval head and vary in length from $\frac{3}{16}$" to 2". They are used for such things as metal trim on store cabinets or fastening house numbers to the structure. Escutcheon pins add a nice appearance to the finish trim and generally match the color of the hardware being installed.

**WARNING!**

Wear a face shield when driving cut nails, because they are subject to breakage, which could do serious damage to an eye.

Common nails are used primarily for rough framing. Box nails, which are thinner and have slightly smaller heads than common nails, are used when working near the edge of the lumber (toenailing studs, for example) because they are less likely to split the wood. Box nails are also used for fastening exterior insulation board and siding.

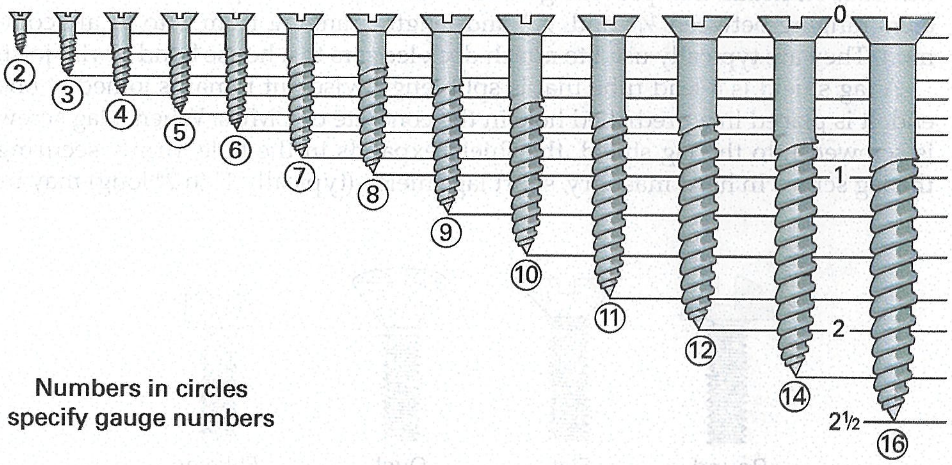
Three types of nails may be used for trim. Finish nails are used primarily for fastening interior trim. Casing nails, which are thicker and have slightly larger heads than finish nails, are used to fasten heavy trim work and exterior finish material. Wire brads are thinner than finish and casing nails and are used for very light trim work such as small moldings. These trim nails all have a small head with a slight indentation, which makes it easy to drive the nail head below the surface of the wood using a nail set.

## 4.1.2 Screws and Bolts

Screws have greater holding power than nails and can easily be removed without damaging the materials involved. However, when selecting the appropriate fastener for a job, screw cost and the time involved in installation must be considered.

### Wood Screws

Wood screws are commonly available in more than 20 different gauges (diameters) and lengths. The screw gauge ranges from 0 to 24 (the higher the number, the larger the diameter). See the wood screw chart in *Figure 34*. Wood screws range in length from $\frac{1}{4}$" to 5".



Numbers in circles specify gauge numbers

**Figure 34** Wood screw chart.

### A Penny's Worth

Back in the fifteenth century, an Englishman could buy 100 three-inch nails for 10 pennies, so the three-inch nail became known as a 10-penny nail. Other nails were known as 8-penny nails, 12-penny nails, and so on, depending on the cost per hundred. Although a penny isn't worth much these days, the designation is still used to identify the nails. The d that is used in the written form (8d, 10d, etc.) is said to represent the denarius, a small Roman coin used in Britain that was equal to a penny.

### Selecting the Right Nail

As a rule of thumb, select a nail that is three times longer than the thickness of the material being fastened. However, the nail length should not exceed the total thickness of the two pieces being fastened together. For example, if you are nailing two 2 × 8 joists where they overlap on a girder, three times the thickness of one joist would be $4\frac{1}{2}$". Since the total thickness of the two joists is only 3", using a $4\frac{1}{2}$" nail would not make sense. The International Building Code® (IBC®) and International Residential Code® (IRC®) also include fastener schedules for connecting various building elements.

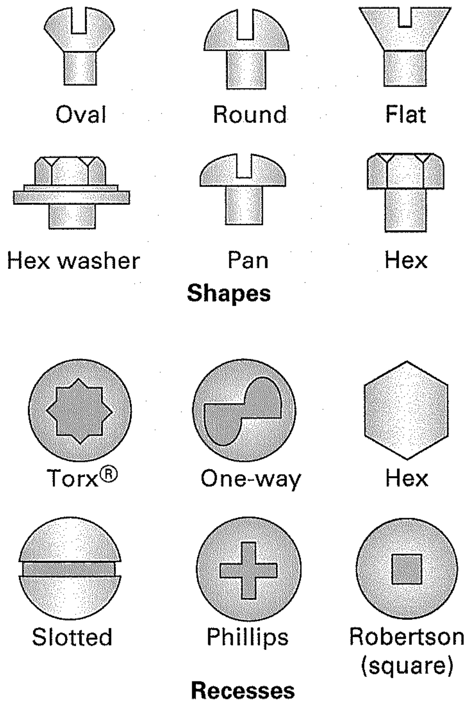


**Figure 35** Common screw head shapes and recesses.

Screws are available with several head shapes, including round, flat, and pan (*Figure 35*). The most common types of screw head recesses are slotted, Phillips, and Robertson (square).

When using wood screws, it is usually necessary to drill pilot holes, particularly in hardwoods, to receive the screw. A pilot hole performs four important functions:

- Ensures pulling the materials tightly together
- Makes the screw easier to drive
- Prevents splitting the wood
- Prevents damage to the screw

For decorative purposes, screws can be obtained in many different finishes (e.g., antique copper or brass, gold- or silver-plated, chromium, lacquered, etc.).

### Sheet-Metal Screws

Sheet-metal screws are used to fasten light-gauge steel framing members to one another and to fasten other building materials to the framing members. Unlike wood screws, the threads of sheet-metal screws extend the entire length of the screw shank. This allows the two pieces being fastened to be drawn tightly together. Because threads of sheet-metal screws are longer and hold better, these screws are also recommended when attaching softer building materials like particleboard and hardboard to steel framing members. Sheet-metal screws are available in approximately the same size range as wood screws.

Pilot holes are not required for sheet-metal screws. Self-tapping sheet-metal screws include self-drilling and self-piercing screws (*Figure 36*). Self-drilling screws have a point like a drill bit that drills a hole for the screw before the threads engage. Self-piercing screws, also known as thread-forming screws, have a sharp point that can penetrate light-gauge metal. As the screw is driven into the material, the threads engage and cut threads in the metal. Sheet-metal screws are typically driven with a power screwdriver.

### Machine Screws

Machine screws are used to fasten butt hinges to metal jambs or door closers to their brackets, and to install lock sets. It may be necessary to drill and tap holes in metal to receive machine screws as fasteners for wood or various kinds of trim. Machine screws have four basic head designs, as shown in *Figure 37*.

Machine screws with a straight slot or Phillips recess are available in diameters ranging from $\frac{1}{16}$" to $\frac{3}{8}$" and lengths of $\frac{1}{8}$" to 3". The most common machine screws are made of steel or brass, but other metals are also used. Machine screws are available in coarse or fine threads.

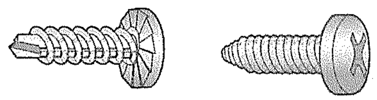
### Lag Screws and Shields

Lag screws (*Figure 38*), or lag bolts, are heavy-duty wood screws with square- or hex-shaped heads that provide greater holding power. Lag screws with diameters ranging between $\frac{1}{4}$" and $\frac{1}{2}$" and lengths ranging from 1" to 6" are common. They are typically used to attach deck ledgers to a house band or rim joist.

A lag shield is a lead tube that is split lengthwise but remains joined at one end. It is placed in a predrilled hole in the concrete or CMUs. When a lag screw is screwed into the lag shield, the shield expands in the hole, firmly securing the lag screw. In hard masonry, short lag shields (typically 1" to 2" long) may be

### Drilling a Pilot Hole

When drilling a pilot hole, use a drill bit that is the same size as the shank of the screw. Hold the drill bit lengthwise over the screw and you should be able to see the threads of the screw. If you can't see the threads, the drill bit is too large. Coating the screw with soap, paraffin, or beeswax makes it easier to drive.



Self-drilling screw

Self-piercing screw

**Figure 36** Sheet-metal screws.

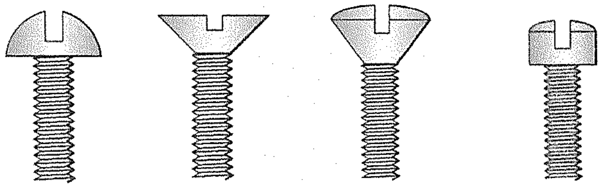


**Figure 37** Machine screws.

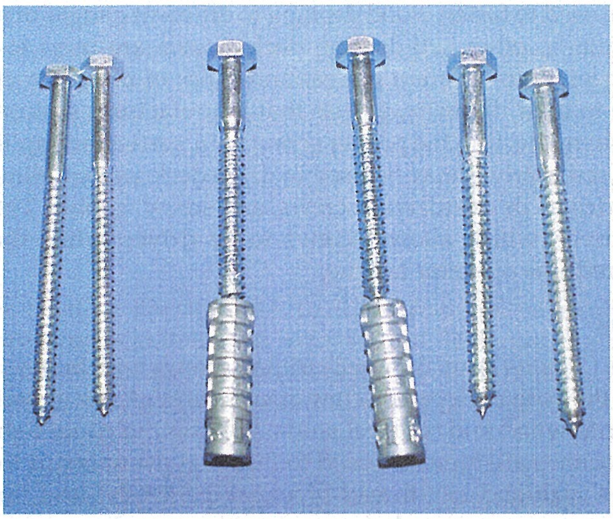


**Figure 38** Lag screws and shields.

used to minimize drilling time. In soft or weak masonry, long lag shields (typically 1½" to 3" long ) should be used to achieve maximum holding strength.

Make sure to use the correct length lag screw to achieve proper shield expansion. The length of a lag screw should be equal to the thickness of the component being fastened plus the length of the lag shield. Also, drill the hole in the masonry to a depth approximately ½" longer than the shield being used. If the head of a lag screw rests directly on wood when installed, a flat washer should be placed under the head to prevent the head from digging into the wood as the lag screw is tightened. Be sure to take the thickness of washers into account when selecting the length of the screw.

### Threaded vs. Nonthreaded Fasteners

For most applications, either threaded or nonthreaded fasteners can be used. However, threaded fasteners are sometimes preferred because they can usually be tightened or removed without damaging the surrounding material. To maintain holding power, ensure you are using the proper-diameter drill bit when drilling the pilot hole. In addition, drill the pilot hole to approximately two-thirds the length of the threaded portion of the screw.

### Concrete/Masonry Screws

Concrete/masonry screws (*Figure 39*), commonly called self-threading anchors, are used to fasten a device or fixture to concrete, CMUs, or brick without using an anchor. To provide a close tolerance between the pilot hole and the screw threads, a specially designed carbide drill bit and installation tool are used when installing these screws. The drill bit and installation tool are typically used with a rotary hammer or hammer-drill. The pilot hole must be drilled to the diameter and depth specified by the screw manufacturer. Once the pilot hole is drilled, the installation tool, along with an appropriate drive socket or bit, are used to drive the screws. When being driven into the concrete, the widely spaced threads on the screws cut into the walls of the hole to provide a tight friction fit. Most types of concrete/masonry screws can be removed and reinstalled to allow for shimming and leveling of the fastened device.

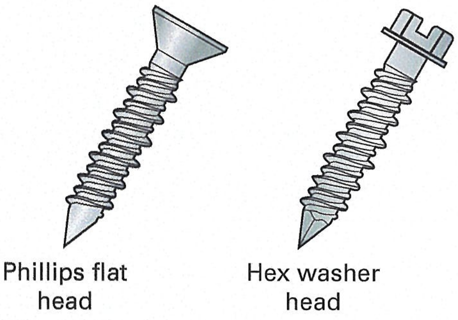


**Figure 39** Concrete screws.

### Deck Screws

Deck screws (*Figure 40*) are available in a wide variety of shapes and sizes for different indoor and outdoor applications. Some deck screws are used to fasten treated lumber and other types of wood decking to wood framing. Self-drilling

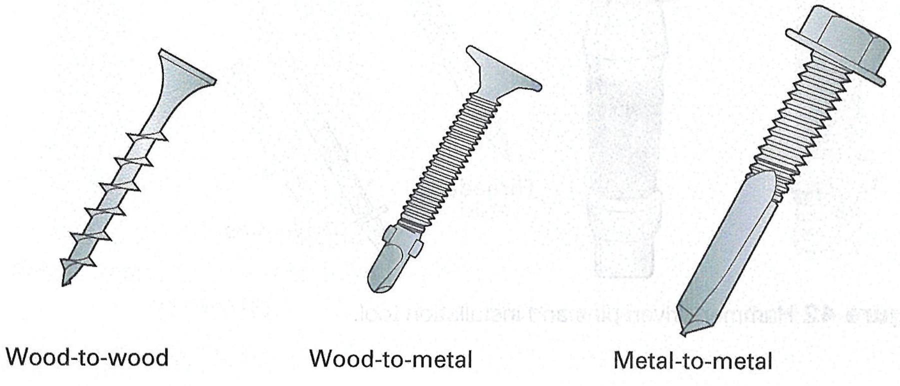


**Figure 40** Typical deck screws.

### 4.1.3 Staples

Staples are manufactured in a wide variety of configurations to do specific jobs. Refer to the manufacturers' catalogs for information regarding uses. Factors that should be considered when selecting staples are:

- Type of point
- Crown (or top) width
- Length
- Type of metal it is made of
- Various coatings available

#### Types of Staples

The type of staple is determined by the type of point it has (*Figure 44*).

- *Chisel*—Recommended for grainy woods; keeps legs parallel to the entire leg length.
- *Crosscut chisel*—Legs penetrate straight and parallel through cross-grain wood. Good for general tacking and nailing purposes.
- *Outside chisel*—Good for clinching inward after penetrating the material being fastened.
- *Inside chisel*—Good for clinching outward after penetrating the material being fastened.
- *Divergent*—After the start of penetration, legs diverge to allow use of longer legs in thin material. This type is good for wallboard insulation.
- *Outside chisel divergent*—Legs diverge, then cross, locking the staple; provides excellent penetration ability.
- *Spear*—Good for penetrating dense materials; will deflect easily when hitting an obstruction.

The most common crown widths vary from $\frac{3}{8}$" to 1". Wider crowns are used mostly for millwork, crating, and the application of asphalt shingles. The most common wire gauge (thickness) is 14 to 16 and the length is normally $\frac{1}{2}$" to 2".

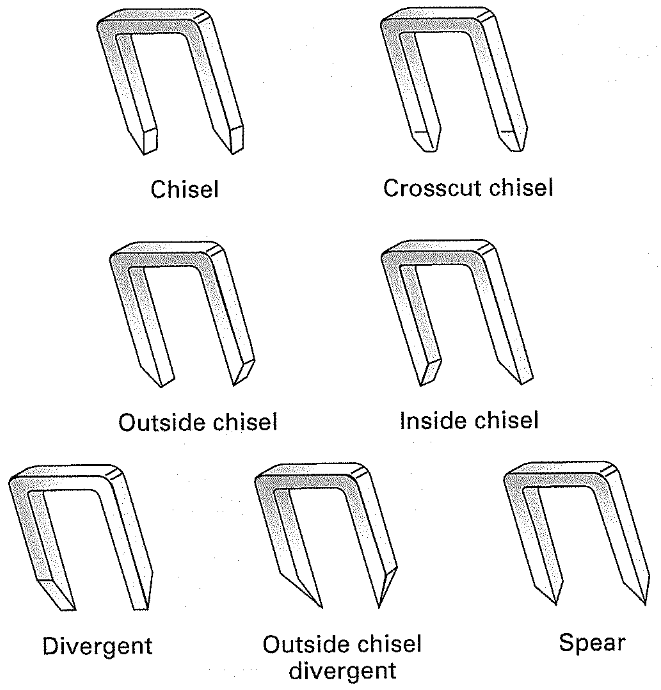


**Figure 44** Types of staples.

Staples are glued together in strips for insertion into a stapler. In addition, the adhesive provides greater holding power. The adhesive melts due to friction when the staple is driven. When it cools, the adhesive bonds well to the base material. Some staplers are manually operated; others are pneumatically or electrically powered.

## 4.2.0 Mechanical Anchors

Mechanical anchors are devices that give fasteners a firm grip in a variety of materials, where the fasteners by themselves would otherwise tend to pull out. Anchors are classified in many ways by different manufacturers. In this module, mechanical anchors are divided into the following broad categories:

- Anchor bolts
- One-step anchors
- Wedge anchors
- Stud bolt anchors
- Sleeve anchors
- One-piece anchors
- Hammer-set anchors
- Bolt-types anchors
- Screw anchors
- Hollow-wall anchors

**High Winds and High Seismic Areas**

In areas that experience high winds and/or seismic activity, uplift lateral and shear connectors are often specified to connect roof to wall, wall to wall, and floors or walls to foundations. Building codes specify where these connectors are required and connector manufacturers provide many options with installation guides.

In addition to the mechanical anchors discussed here, a wide variety of specialty anchors are also available from suppliers.

### 4.2.1 Anchor Bolts

One of the most common anchors in frame construction is the anchor bolt. Anchor bolts are commonly used to anchor the sill plate to a concrete or CMU foundation (*Figure* 45). In addition, larger anchors bolts (ranging from 2½" to 5" in diameter and 10' to 12' long) may be used to attach equipment to its foundation. Anchor bolts must be accurately positioned and affixed prior to concrete placement. The anchor bolt position must once again be checked to ensure the bolt did not become displaced during concrete placement. The sill plate is then placed over the anchor, and a washer and nut are used to secure the sill plate to the foundation. The sill plate is the base for the floor framing.

### 4.2.2 One-Step Anchors

One-step anchors are designed to be installed through the mounting holes in the component to be fastened. Initially, the anchor and the hole into which the anchor is installed have the same diameter. As the bolt or screw is tightened, the anchor expands to create a tight fit in the hole. One-step anchors are available

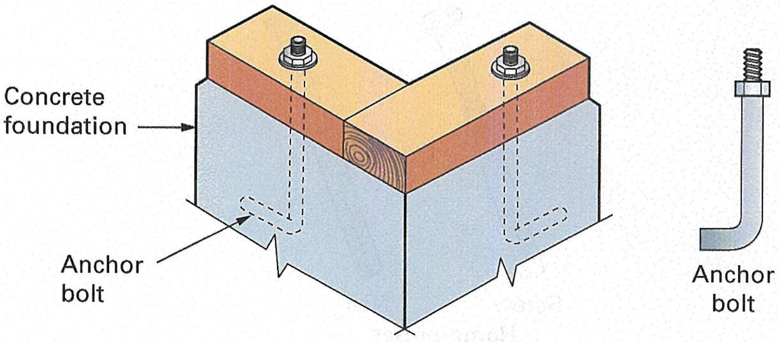


**Figure 45** Anchor bolts.

in various diameters ranging from ¼" to 1¼" and lengths ranging from 1¾" to 12". Wedge, stud bolt, sleeve, one-piece, and screw and nail hammer-set anchors (*Figure 46*) are common types of one-step anchors.

### 4.2.3 Wedge Anchors

Wedge anchors are heavy-duty anchors supplied with nuts and washers. The drill bit size used for the hole is the same diameter as the anchor. The depth of the hole is not critical as long as it meets the minimum manufacturer recommendations. Clean the hole of dust and other material, insert the anchor into the hole, and drive it with a hammer far enough so that at least six threads are below the top surface of the component. Then, tighten the anchor nut to expand the anchor and secure it in the hole.

### 4.2.4 Stud Bolt Anchors

Stud bolt anchors are heavy-duty threaded anchors commonly used to level components or equipment fastened to them. These anchors are designed to fit to the bottom in its mounting hole; therefore, it is critical that the hole depth specified by the manufacturer is achieved to ensure proper expansion. Clean the hole of dust and other material, then insert the anchor in the hole with the expander plug end down. Drive the anchor into the hole with a hammer or setting tool to expand the anchor and tighten it in the hole. The anchor is fully set when it can no longer be driven into the hole. Fasten the component or equipment to the anchor using a bolt with the correct size and thread type.

One type of stud bolt anchor, called a TZ® expansion anchor, is a medium-duty anchor especially suited for seismic and safety-relevant applications. TZ® expansion anchors can be used in cracked and uncracked concrete, and are available in ⅜" to ¾" diameters and in lengths ranging from 3" to 10".

### 4.2.5 Sleeve Anchors

Sleeve anchors are multipurpose anchors. The depth of the anchor hole is not critical as long as the minimum depth recommended by the manufacturer is drilled. Clean the hole of dust and other material, insert the anchor into the hole, and tap it until it is flush with the component. Tighten the anchor nut or bolt to expand the anchor and tighten it in the hole.

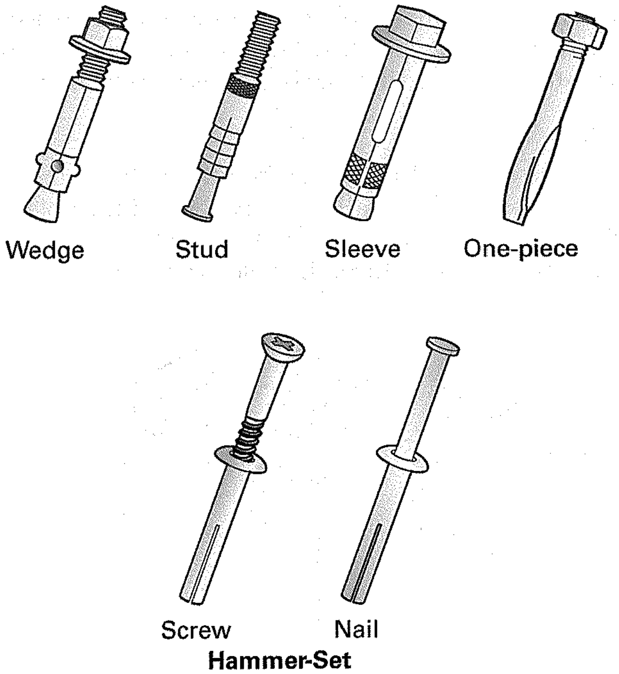


**Figure 46** One-step anchors.

### 4.2.6 One-Piece Anchors

One-piece anchors are multipurpose anchors. They work on the principle that as the anchor is driven into the hole, the spring force of the expansion mechanism is compressed and flexes to fit the size of the hole. Once set, it tries to regain its original shape. The depth of the hole drilled in the masonry must be at least one-half inch deeper than the required embedment. The proper depth is critical. Overdrilling is as bad as underdrilling. Clean the hole of dust and other material, insert the anchor through the component, and drive it into the hole with a hammer until the head is firmly seated against the component. It is important to make sure that the anchor is driven to the proper embedment depth. Some manufacturers make specially designed drivers and installation tools. These tools allow anchors to be installed in confined spaces and help prevent damage to the component from stray hammer blows.

### 4.2.7 Hammer-Set Anchors

Hammer-set anchors are made for use in concrete and masonry. There are two types of hammer-set anchors: screw and nail. An advantage of the screw-type anchors is that they are removable. Both types have a diameter the same size as the anchoring hole. For both types, the anchor hole must be drilled to the diameter of the anchor and to a depth at least a quarter-inch deeper than that required for embedment. Clean the hole of dust and other material, then insert the anchor into the hole through the mounting holes in the component to be fastened. Drive the screw or nail into the anchor body to expand it. It is important to make sure that the head is seated firmly against the component and is at the proper embedment depth.

### 4.2.8 Bolt-Type Anchors

Bolt-type anchors are designed to secure two or more pieces of material together. Threaded rod may be used with some types of bolt-type anchors. Drop-in and expansion anchors (*Figure 47*) are common types of bolt-type anchors. Self-drilling anchors are another type of bolt-type anchor.

#### Drop-In Anchors

Drop-in anchors are typically used for heavy-duty applications. There are two types of drop-in anchors. The first type, made for use in solid concrete and filled masonry, has an internally threaded expansion anchor with a preassembled internal expander plug. A pilot hole must be drilled to the diameter and depth specified by the manufacturer. Clean the hole of dust and other material, insert the anchor into the hole, and tap it until it is flush with the surface. Drive the setting tool supplied with the anchor into the anchor to expand it. Position the component to be fastened in place, and thread and tighten the correct-size machine bolt into the anchor.

The second type of drop-in anchor, called a hollow-set anchor, is made for use in hollow concrete and masonry base materials. They can also be used in solid concrete and filled masonry. Hollow-set drop-in anchors have a slotted, tapered expansion sleeve and a serrated expansion cone. The anchor hole must be drilled to the diameter specified by the manufacturer. When installed in hollow base materials, drill the hole into the cell or void. Clean the hole of dust and other material, insert the anchor into the hole, and tap it until it is flush with the surface. Position the component to be fastened in place, then thread the proper-size machine bolt or screw into the anchor and tighten it to expand the anchor in the hole.

#### Expansion Anchors

Single- and double-expansion anchors are made for use in concrete and other masonry. Double-expansion anchors are used mainly when fastening into concrete or masonry of questionable strength. For both types, the anchor hole must be drilled to the diameter and depth specified by the manufacturer. Clean the hole of dust and other material, then insert the anchor into the hole, threaded cone end first. Tap it until it is flush with the surface. Position the component to

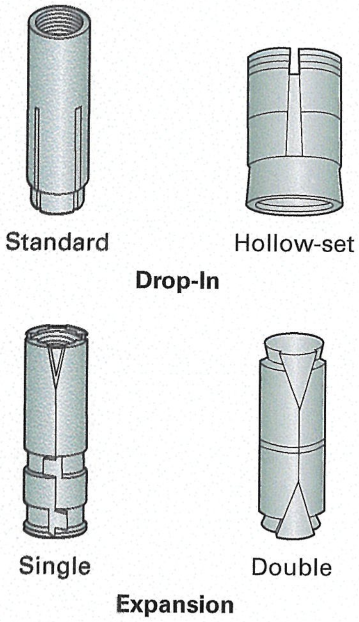


**Figure 47** Bolt-type anchors.

be fastened in place, then thread the proper-size machine bolt into the anchor and tighten it to expand the anchor in the hole.

### Self-Drilling Anchors

Self-drilling anchors are used in concrete and masonry (*Figure 48*). Some types of self-drilling anchors have a cutting sleeve that is first used as a drill bit and later becomes the expandable anchor itself. A rotary hammer is used to drill the hole in the concrete or masonry using the cutting sleeve. After drilling the hole, pull the sleeve out and clean the hole. Then, insert the anchor's expander plug into the cutting end of the sleeve. Drive the sleeve and expander plug into the hole with the rotary hammer until they are flush with the surface. As the sleeve is hammered down, it hits the bottom, where the tapered expander plug causes the fastener to expand and lock into the hole. The anchor is then snapped off at the shear point with a quick lateral movement of the hammer. The component to be fastened can then be attached to the anchor using the proper-size bolt.

### Guidelines for Installing Anchors in Hardened Concrete or Masonry

When selecting masonry anchors, regardless of the type, always take into consideration and follow the manufacturer's recommendations pertaining to hole diameter and depth, minimum embedment in concrete, maximum thickness of the material to be fastened, and the pullout and shear load capacities.

When installing anchors and/or stud bolt anchors in hardened concrete, make sure the area where the equipment or component is to be fastened is smooth so it will have solid footing. An uneven footing might cause the equipment to twist, warp, not tighten properly, or vibrate when in operation. Before starting, carefully inspect the rotary hammer or hammer-drill and the drill bit(s) to ensure they are in good operating condition. Set the drill or hammer-drill depth gauge to the required depth of the hole. Be sure to use the type of carbide-tipped

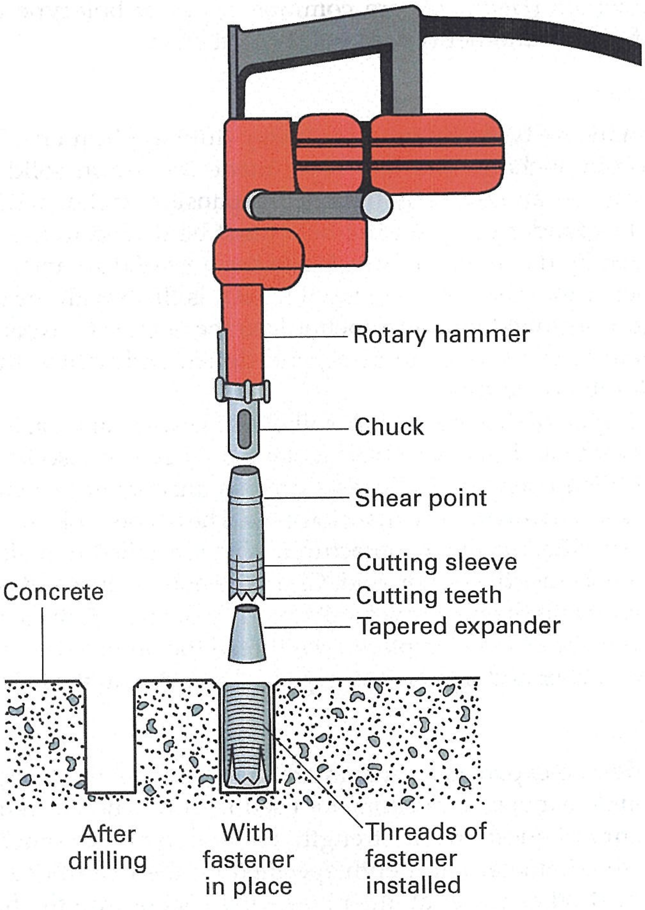


**Figure 48** Self-drilling anchor.

masonry or rotary hammer bits recommended by the drill/hammer or anchor manufacturer because these bits are made to take the higher impact of the masonry materials. When drilling into concrete or masonry, do not force the bit into the material by pushing down hard on the drill. Use a little pressure and let the drill do the work. For large holes, start with a smaller bit, then change to a larger bit.

The methods for installing the different types of anchors in hardened concrete or masonry were briefly described in this section. Always install the selected anchors according to the manufacturer's specifications. The following is an example of a typical procedure used to install many types of expansion anchors in hardened concrete and masonry. Refer to *Figure 49* as you study the procedure.

**WARNING!**

Drilling in concrete generates noise, dust, and flying particles. Always wear safety glasses, ear protection, a dust mask, and gloves. Ensure that other workers in the area are also wearing protective equipment before you begin drilling.

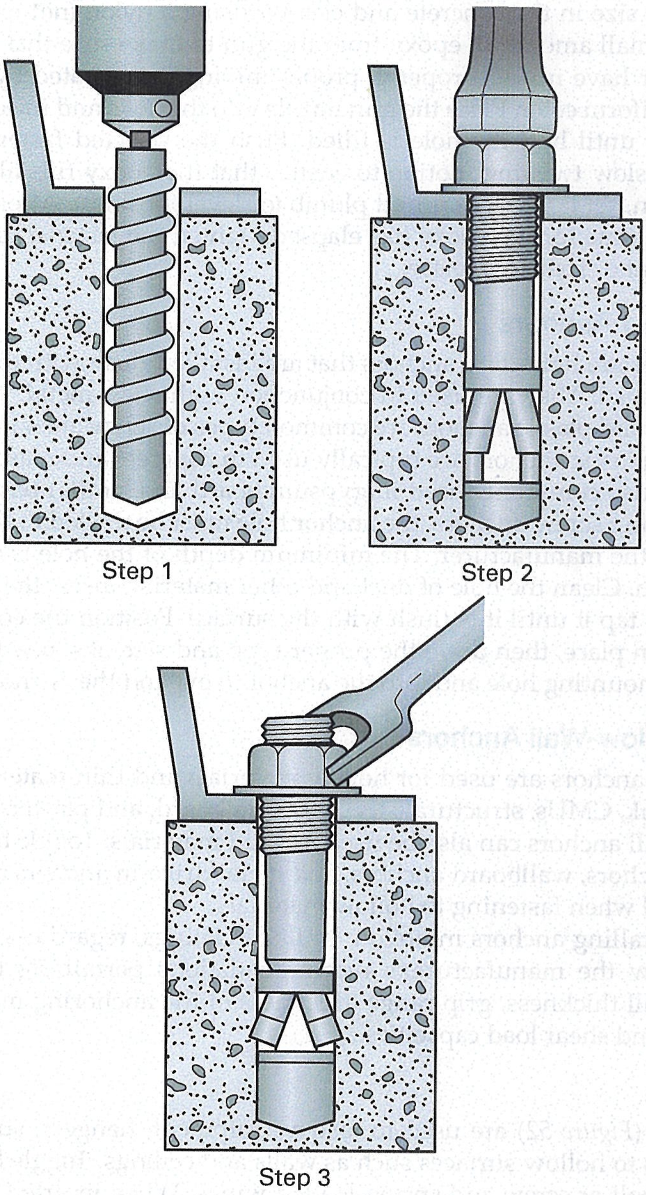


**Figure 49** Installing an anchor bolt in hardened concrete.

**Step 1** Drill the anchor bolt hole the same diameter as the anchor bolt. The hole must be deep enough for six threads of the bolt to be below the surface of the concrete. Clean out the hole using a squeeze bulb.

**Step 2** Drive the anchor bolt into the hole using a hammer. Protect the threads of the bolt with a nut that does not allow any threads to be exposed.

**Step 3** Put a washer and nut on the bolt, and tighten the nut with a wrench until the anchor is secure in the concrete.

### Epoxy Anchoring Systems

**Catalyst**: A substance that causes a reaction in another substance.

Epoxy anchoring systems can be used to anchor threaded rods, dowels, and other fasteners in solid concrete, CMUs, and brick. For one type of epoxy anchoring system, a two-part epoxy is packaged in a two-chamber cartridge that keeps the **catalyst** and hardener ingredients separated until use. This cartridge is placed into a special tool resembling a caulking gun. When the gun handle is pumped, the epoxy catalyst and hardener are mixed within the gun; then the epoxy is ejected from the gun nozzle.

To use epoxy to install an anchor in solid concrete (*Figure 50*), drill a hole of the proper size in the concrete and clean it using a nylon (not metal) brush. Dispense a small amount of epoxy from the gun to make sure that the catalyst and hardener have mixed properly; proper mixing is indicated by the epoxy being of a uniform color. Place the gun nozzle into the hole, and inject the epoxy into the hole until half the hole is filled. Push the selected fastener into the hole using a slow twisting motion to ensure that the epoxy fills all voids and crevices. Then, set it to the required plumb (or level) position. After the recommended cure time for the epoxy has elapsed, tighten the fastener nut to secure the component or fixture in place.

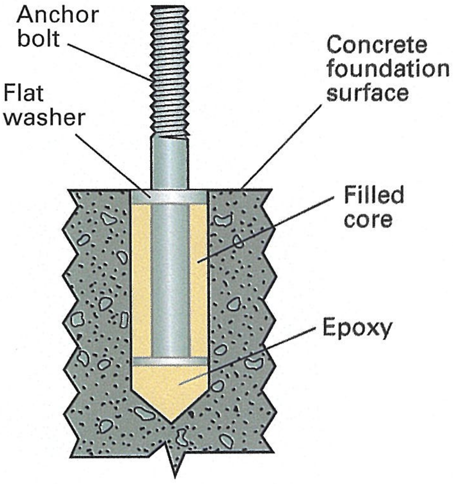


**Figure 50** Fastener anchored in epoxy.

## 4.2.9 Screw Anchors

Screw anchors are light-duty anchors that are installed flush with the surface of the base material. They are used in conjunction with sheet-metal, wood, or lag screws. Fiber and plastic anchors are common types of screw anchors (*Figure 51*).

Fiber and plastic anchors are typically used in concrete and masonry. Plastic anchors are also commonly used in gypsum board and similar base materials. When installing screw anchors, the anchor hole must be drilled to the diameter specified by the manufacturer. The minimum depth of the hole is equal to the anchor length. Clean the hole of dust and other material, insert the anchor into the hole, and tap it until it is flush with the surface. Position the component to be fastened in place, then drive the proper type and size of screw through the component mounting hole and into the anchor to expand the anchor.

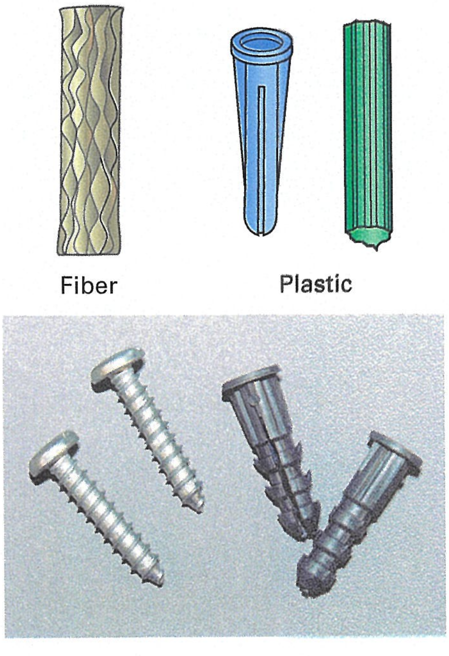


**Figure 51** Screw anchors and screws.

## 4.2.10 Hollow-Wall Anchors

Hollow-wall anchors are used for hollow materials and thin materials such as concrete plank, CMUs, structural steel, gypsum board, and plaster. Some types of hollow-wall anchors can also be used in solid materials. Toggle bolts, sleeve-type wall anchors, wallboard anchors, and metal drive-in anchors are common anchors used when fastening to hollow materials.

When installing anchors in hollow walls or ceilings, regardless of the type, always follow the manufacturer's recommendations pertaining to use, hole diameter, wall thickness, grip range (thickness of the anchoring material), and the pullout and shear load capacities.

### Toggle Bolts

Toggle bolts (*Figure 52*) are used to fasten equipment, hangers, supports, and similar items to hollow surfaces such as walls and ceilings. Toggle bolts consist of a slotted bolt or screw and spring-loaded wings. When inserted through the item to be fastened, then through a predrilled hole in the wall or ceiling, the

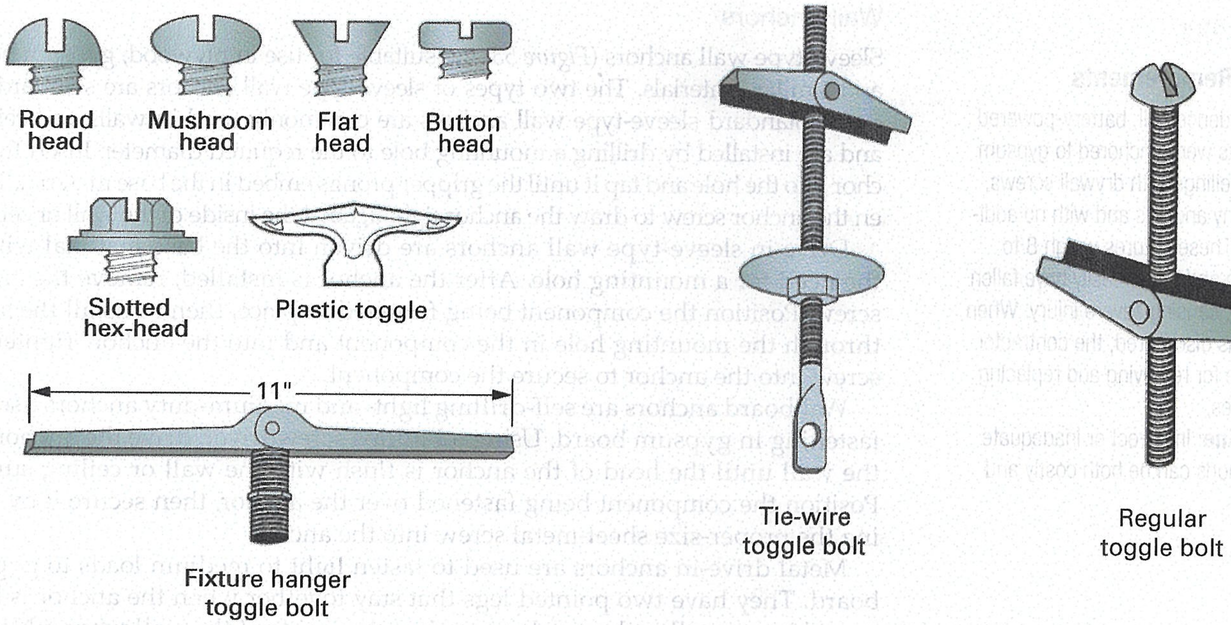


**Figure 52** Toggle bolts.

wings spring apart and provide a firm hold on the inside of the hollow wall or ceiling as the bolt is tightened. Note that the hole drilled in the wall or ceiling should be just large enough for the compressed wings to pass through. Once the toggle bolt is installed, be careful not to completely unscrew the bolt because the wings will fall off, making the fastener useless. Screw-actuated plastic toggle bolts are also available. The plastic toggle bolts are similar to metal toggle bolts, but they come with a pointed screw and do not require as large a hole. Unlike the metal version, the plastic wings remain in place if the screw is removed.

Toggle bolts are used to fasten a part to hollow block, gypsum board, plaster, panel, or tile. The following procedure can be used to install toggle bolts:

**Toggle Bolts**

What will happen if a toggle bolt is fastened too tightly?

**WARNING!**

Follow all safety precautions to avoid injury.

**Step 1** Select the proper-size toggle bolt and drill bit for the job.

**Step 2** Check the toggle bolt for damaged or dirty threads or a malfunctioning wing mechanism.

**Step 3** Drill a hole completely through the surface to which the part is to be fastened.

**Step 4** Insert the toggle bolt through the opening in the item to be fastened.

**Step 5** Screw the wings onto the end of the toggle bolt, ensuring that the flat side of the wing is facing the bolt head.

**Step 6** Fold the wings completely back and push them through the drilled hole until the wings spring open.

**Step 7** Pull back on the item to be fastened to hold the wings firmly against the inside surface to which the item is being attached.

**Step 8** Tighten the toggle bolt with a screwdriver until it is snug.

**CASE HISTORY**

### Installation Requirements

In a college residence hall, battery-powered emergency lights were anchored to gypsum board hallway ceilings with drywall screws, without using any anchors and with no additional support. These fixtures weigh 8 to 10 pounds each and might easily have fallen from the ceiling, causing severe injury. When the situation was discovered, the contractor was responsible for removing and replacing dozens of fixtures.

**The Bottom Line**: Incorrect or inadequate anchoring methods can be both costly and dangerous.

### Wall Anchors

Sleeve-type wall anchors (*Figure 53*) are suitable for use in plywood, gypsum board, and similar materials. The two types of sleeve-type wall anchors are standard and drive. Standard sleeve-type wall anchors are commonly used in walls and ceilings and are installed by drilling a mounting hole to the required diameter. Insert the anchor into the hole and tap it until the gripper prongs embed in the base material. Tighten the anchor screw to draw the anchor tight against the inside of the wall or ceiling.

Drive-in sleeve-type wall anchors are driven into the base material without the need for a mounting hole. After the anchor is installed, remove the anchor screw. Position the component being fastened in place, then reinstall the screw through the mounting hole in the component and into the anchor. Tighten the screw into the anchor to secure the component.

Wallboard anchors are self-drilling light- and medium-duty anchors used for fastening in gypsum board. Using a Phillips screwdriver, drive the anchor into the wall until the head of the anchor is flush with the wall or ceiling surface. Position the component being fastened over the anchor, then secure it by driving the proper-size sheet-metal screw into the anchor.

Metal drive-in anchors are used to fasten light to medium loads to gypsum board. They have two pointed legs that stay together when the anchor is hammered into a wall and spread out against the inside of the wall when a No. 6 or No. 8 sheet-metal screw is driven in.

The procedure for installing a fastener in a hollow CMU wall or brick when using epoxy is basically the same as the one just described. The difference is that the epoxy is first injected into an anchor screen to fill the screen, then the anchor screen is installed into the drilled hole. Use of the anchor screen is necessary to hold the epoxy intact in the hole until the anchor is inserted into the epoxy.

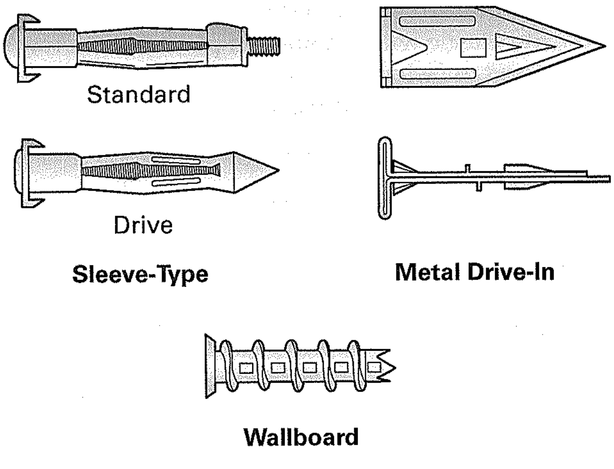


**Figure 53** Sleeve-type, metal drive-in, and wallboard anchors.

## 4.3.0 Adhesives

**Adhesives**: Describes a wide variety of products, including glues, used to attach one material to another.

The term **adhesives** describes a variety of products that are used to attach one material to another. Construction adhesives are used to attach paneling or gypsum board to framing, and to install subflooring.

Glues have a wide range of characteristics. Some are quick drying; others are slow. Some are waterproof; some are not. Because they each have specific characteristics, it is important to know what adhesive to use in a particular situation. At some point in your career, this knowledge of adhesives will become second nature. In the meantime, consult a professional such as a building supply specialist. Always read the instructions on the label before using any adhesive. Also keep in mind that new products are being introduced all the time, so it is important to keep up with what is going on in the industry.

Remember that most adhesives are made from chemicals, some of which are toxic and/or flammable. Read and follow the safety instructions on the label and check the safety data sheet (SDS). The SDS for any toxic or flammable substance must be available at the jobsite. In general, it is a good idea to work with adhesives in a well-ventilated area away from open flames, and to wear a face mask and eye protection.

SDSs are fact sheets prepared by the chemical manufacturer or importer. Each product used on a construction site must have an SDS. An SDS describes the substance, along with its hazards, safe handling, first aid, and emergency spill procedures. The HAZCOM standard requires new SDSs (formerly known as material safety data sheets or MSDSs) to be in a standardized format. The sections of the form include the following:

- *Section 1, Product identification, manufacturer contact information, recommended uses and restrictions*
- *Section 2, Hazard identification*
- *Section 3, Composition/information on ingredients*
- *Section 4, First aid measures*
- *Section 5, Firefighting information*
- *Section 6, Incidental release measures*
- *Section 7, Handling and storage*
- *Section 8, Exposure controls/personal protection*
- *Section 9, Physical and chemical properties*
- *Section 10, Stability and reactivity*
- *Section 11, Toxicological properties*
- *Section 12, Ecological properties*
- *Section 13, Disposal considerations*
- *Section 14, Transport information*
- *Section 15, Regulatory information*
- *Section 16, Other information*

### 4.3.1 Glues

Glues are used in laminated construction such as arches, curved members, and beams. They are available in two forms: liquid or dry. The dry forms are mixed into water on the job. Some glues are provided in two or more liquid forms that when mixed together in proper proportions create a very strong adhesive. In cases where mixing is involved, the manufacturer's SDS instructions must be followed, for both the quality desired and safety.

Some of the most common types of glue for building framing are:

- *Casein glue*—Available in a powder form that is mixed with water. Casein glue can be used in temperatures down to 35°F. It is water resistant and should be used only on oily woods. Under normal circumstances, casein glue will last for years; however, the powder tends to deteriorate with age.
- *Urea formaldehyde or plastic resin glue*—Available in powder form that is mixed with water. It is slow setting and has good resistance to heat and water. It is not recommended for oily woods. It is often used for laminated timbers and general woodworking where moisture is present.
- *Resorcinol resin or waterproof glue*—An expensive glue that is provided in two liquid chemical parts. One part acts as a catalyst on the hardener when the two parts are mixed together. It is excellent for use in exterior woodwork or laminated timbers that are exposed to extremely cold temperatures. Eye goggles and a respirator are required when mixing and working with this glue.

**WARNING!**

Observe all SDS precautions for this material. Extreme caution must be taken when using contact cement, as it is highly flammable. It should be used in a well-ventilated area, as the fumes can overcome a worker.

**Adhesive Safety**

Some types of adhesives emit noxious and harmful vapors before they cure (dry). Observe the following general safety precautions when using adhesives:

- Ensure good ventilation is provided.
- Keep all flames and lit tobacco products out of the area.
- Make sure switches, electric tools, or other sparking devices are not used in the area.
- Close off any area where people who are smoking could wander through.
- Do not breathe vapors for any length of time.
- Immediately remove any adhesive that comes in contact with your skin.
- Wear protective goggles and clothing when required.
- Follow the manufacturer's SDS instructions and check the label on the container for specific safety precautions.
- When in doubt, ask questions.

### 4.3.2 Construction Adhesives

Construction adhesives are available for many types of heavy-duty construction applications such as installing paneling, structural decking, and gypsum board. In addition to providing a strong bond between materials, construction adhesives offer such advantages as sound deadening and the bonding of dissimilar materials such as wood, gypsum, glass, metal, and concrete.

Construction adhesives are typically applied from a cartridge with a manual ratchet-type caulking gun or pneumatic caulking gun (*Figure 54*). Cartridges range in capacity from about 10 ounces to 30 ounces.

Some adhesives are designed to fasten sheet materials to framing members. They include the following:

- *Construction adhesive*—Used to apply wood or gypsum board to framing members. It has a solvent base. A caulking gun is used to apply construction adhesive.
- *Neoprene adhesive*—Can be used to attach wood to wood and gypsum to wood or metal. Neoprene adhesive will also bond to concrete. Like construction adhesive, neoprene adhesive is also applied with a caulking gun. Neoprene adhesive also has a solvent base.
- *Epoxy*—Made by mixing a catalyst and a hardening agent at the time of use. Epoxies are good for bonding dissimilar materials. Fast-acting epoxies set almost instantly. Epoxies are typically provided in special syringe-type applicators that keep the two components separate until needed. The catalyst and hardener blend together when the plungers are depressed. Slower-setting epoxies are mixed in a container at the jobsite.

**WARNING!**

Many adhesives and cements are flammable and/or explosive. Ensure they are stored in a well-ventilated area and always read all warning labels on the adhesive packaging. Take the proper precautions to avoid an explosion or fire.

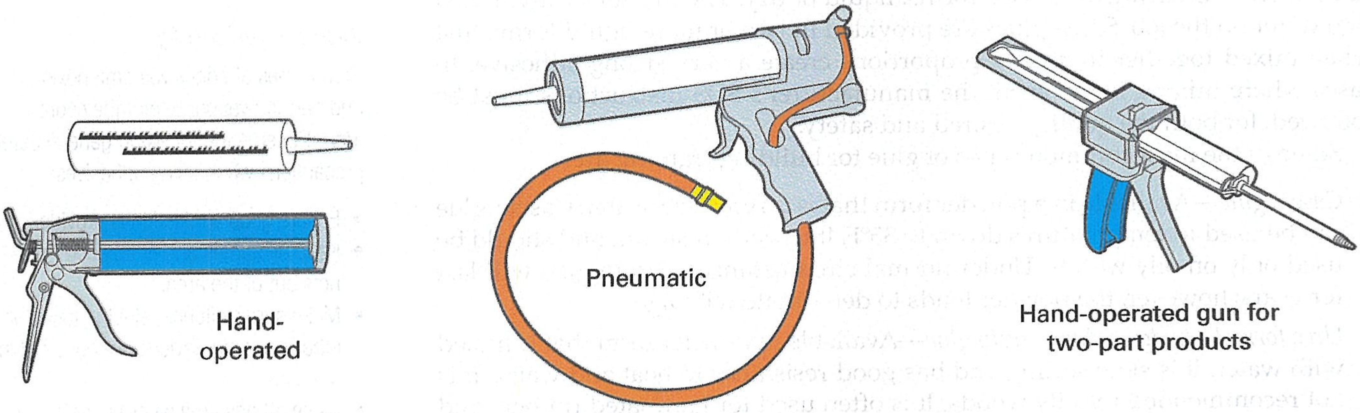

Hand-operated
Pneumatic
Hand-operated gun for two-part products

**Figure 54** Adhesive applicators.

### 4.3.3 Shelf Life

All adhesives have a limited shelf life (life span) that ranges from 12 to 24 months. If they are not used within that time, the adhesives will begin to lose their bonding ability. Most manufacturers claim a shelf life of at least two years. Keep in mind, however, that three to six months or more may have elapsed from the time the adhesive was manufactured until it was purchased. When purchasing adhesives, write the date on the container and do not use it beyond the shelf life listed on the label.

## 4.0.0 Section Review

1. A carpenter who wants to attach a steel stud to a concrete floor typically uses a _____.
   a. concrete-coated nail
   b. powder-actuated fastener
   c. masonry nail
   d. roofing nail

2. In soft or weak masonry, maximum holding strength is achieved by using a lag shield that is _____.
   a. extra thick
   b. long
   c. narrow
   d. short

3. To penetrate dense materials, use staples with _____.
   a. spear points
   b. outside chisel points
   c. divergent points
   d. inside chisel points

4. When installing screw anchors, the minimum depth of the drilled hole is _____.
   a. twice the anchor length
   b. three times the width of the anchor
   c. equal to the anchor length
   d. no deeper than 1 inch

5. An epoxy anchoring system consists of two parts: a catalyst and a(n) _____.
   a. resin
   b. adhesive
   c. hardener
   d. filler

## Module 27102 Review Questions

1. One of the most common injuries associated with wood products is _____.
   a. pinching
   b. carpal tunnel
   c. splinters
   d. pinched nerves

2. Silica is a mineral found in _____.
   a. concrete
   b. pressure-treated wood
   c. steel
   d. slag

3. When performing a job hazard analysis, tasks are broken down into _____.
   a. steps
   b. phases
   c. chapters
   d. codes

4. In the grading stamp shown in *RQ01*, the term S-DRY means that the lumber _____.

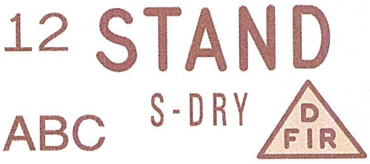


**Figure RQ01**

   a. is made from standard dry wood
   b. has a maximum 19 percent moisture content
   c. has a maximum 15 percent moisture content
   d. has a moisture content over 19 percent

5. Plywood that is typically used to manufacture doors, furniture, and cabinets is known as _____.
   a. softwood plywood
   b. finished plywood
   c. hardwood plywood
   d. premium plywood

6. The panel product that will not support combustion and will not burn is _____.
   a. plywood
   b. particleboard
   c. OSB
   d. mineral fiberboard

7. An engineered wood product commonly used to make doors and other millwork is _____.
   a. glulam
   b. LVL
   c. PSL
   d. LSL

8. The typical aggregate content of concrete is approximately _____.
   - a. 30–50%
   - b. 40–60%
   - c. 50–70%
   - d. 60–80%

9. The nominal dimensions of a typical concrete masonry unit are _____.
   - a. 8 × 8 × 16 inches
   - b. 4 × 4 × 8 inches
   - c. 6 × 12 × 8 inches
   - d. 2 × 4 × 12 inches

10. How many 4' × 8' sheets of plywood would be needed to provide subfloor for a 20' by 25' room?
    - a. 16
    - b. 20
    - c. 24
    - d. 32

11. When calculating the amount of concrete needed, the unit of measure is _____.
    - a. short tons
    - b. cubic meters
    - c. cubic yards
    - d. foot-pounds

12. Material-handling accidents are most likely to happen when _____.
    - a. the weather is bad
    - b. equipment is defective
    - c. the job is behind schedule
    - d. workers are new or inexperienced at a job

13. When lifting an object, it is best to _____.
    - a. bend over at the waist
    - b. lift with your legs
    - c. use only your back muscles
    - d. raise the load as quickly as possible

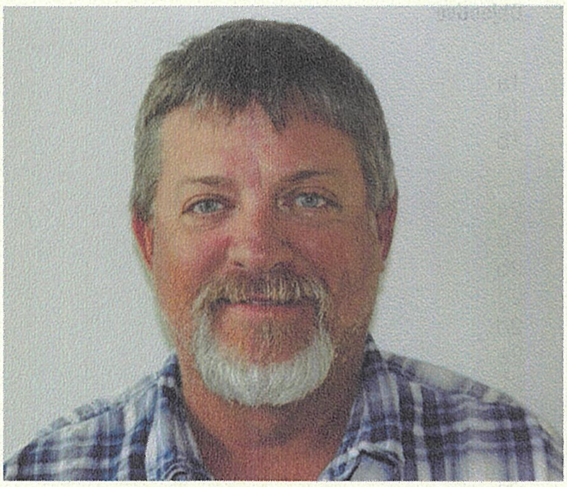
14. In construction, the most common fasteners used for attaching two pieces of lumber are _____.
    - a. nails
    - b. lag bolts
    - c. rivets
    - d. wood screws

15. The type of bolt used to attach the sill plate to a foundation is the _____.
    - a. machine bolt
    - b. carriage bolt
    - c. anchor bolt
    - d. stove bolt

16. The two types of hammer-set anchors are _____.
    - a. screw and nail
    - b. bolt and toggle
    - c. expansion and post
    - d. sleeve and wedge
17. Self-drilling anchors are used in _____.
    - a. gypsum board
    - b. steel and concrete
    - c. plywood and lumber
    - d. concrete and masonry
18. When obtaining safety information about an adhesive, the best source of reliable information is _____.
    - a. your supervisor
    - b. a coworker
    - c. a building supply dealer
    - d. the applicable SDS
19. An adhesive that requires two components to be mixed together at the time of use is _____.
    - a. polyvinyl glue
    - b. epoxy
    - c. contact cement
    - d. mastic
20. Which of the following is applied with a caulking gun and used to adhere gypsum board to framing members?
    - a. Resorcinol glue
    - b. Construction adhesive
    - c. Contact cement
    - d. Polyvinyl glue

Answers to Section Review Questions and Odd-Numbered Module Review Questions are found in *Appendix A*.

# Cornerstone of Craftsmanship



**Tim Mosley**
*The Haskell Company, Manager of Field Personnel*

### How did you choose a career in the industry?

High school vocational classes. I was able to find an elective, so I selected carpentry and my backup was electrical. When classes were assigned, carpentry was my first choice.

### Who inspired you to enter the industry?

My Uncle Marvin. While working a hay field during a hot summer, he asked me what I was going to do. His advice was to find a trade, then pursue a career. Construction has paved the road for me to take this approach.

### What types of training have you been through?

I've taken high school carpentry class, and an apprenticeship program. Along with these classes, I have taken many classes on leadership, Spanish as a second language, and computer classes. Never stop learning. Besides craft training, leadership training has been some of the most important I have received.

### How important are education and training in construction?

You never stop learning. Formal training gives you an advantage. I have seen firsthand what team members with formal training know versus team members who have just been shown how to perform a task. Team members with formal training tend to see the bigger picture.

### What kinds of work have you done in your career?

I started in residential framing and roofing, then moved to form carpentry. This craft experience and training led me to management with The Haskell Company. I now manage all field craftworkers for The Haskell Company.

### Tell us about your present job.

I am the Manager of Field Personnel for The Haskell Company. In my job, I staff all of our projects with the needed personnel.

### What do you enjoy most about your job?

Recruiting team members and watching them become successful. I also enjoy being a mentor to those who want to grow and are striving for better things.

### What factors have contributed most to your success?

Loyalty, dedication, eagerness to excel, and never turning down an opportunity.

### Would you suggest construction as a career to others?

The construction industry offers many avenues to becoming successful. You can start as an entry-level craftworker, and with determination and a willingness to do more, you can develop your career based on your craft experience.

### What advice would you give to those new to the field?

Establish 5-year goals and look for a company that will help you achieve them.

### What are some interesting career-related facts or accomplishments?

I have only worked for one company since high school and I have had 9 promotions. I have been with The Haskell Company for 36 years. During my tenure here, I have also been given the opportunity to visit and/or work in 39 other states.

### How do you define craftmanship?

Respected professional work done with pride and utmost quality.

# APPENDIX A Answer Key

| Answer | Section | Objective |
|---|---|---|
| **Section One** | | |
| 1. a | 1.1.0 | 1a |
| 2. c | 1.1.4 | 1a |
| 3. b | 1.2.1 | 1b |
| **Section Two** | | |
| 1. b | 2.1.3 | 2a |
| 2. c | 2.1.6 | 2a |
| 3. a | 2.2.1 | 2b |
| 4. a | 2.3.0 | 2c |
| 5. b | 2.4.0 | 2d |
| 6. d | 2.5.2 | 2e |
| 7. a | 2.6.1 | 2f |
| **Section Three** | | |
| 1. a | 3.1.3 | 3a |
| 2. c | 3.1.8 | 3a |
| **Section Four** | | |
| 1. b | 4.1.1 | 4a |
| 2. b | 4.1.2 | 4a |
| 3. a | 4.1.3 | 4a |
| 4. c | 4.2.9 | 4b |
| 5. c | 4.3.2 | 4c |
| **Module Review** | | |
| 1. c | 1.1.3 | |
| 3. a | 1.2.1 | |
| 5. c | 2.3.1 | |
| 7. d | 2.3.2 | |
| 9. a | 2.4.5 | |
| 11. c | 2.6.3 | |
| 13. b | 3.1.3 | |
| 15. c | 4.2.1 | |
| 17. d | 4.2.8 | |
| 19. b | 4.3.2 | |

# APPENDIX B Common Hardwoods and Softwoods

| Tree | Use | Class (H—Hard, S—Soft) |
|---|---|---|
| Alder | Used in cabinets and furniture. The color is reddish-brown. Alder is a less expensive substitute for cherry. It is also known as red alder or fruitwood. | H |
| Ash | Coarse-grained, hard, and heavy. The heartwood is brown; the sapwood is almost white. Used for furniture, cabinets, trim, tool handles, and plywood. | H |
| Basswood | One of the softest hardwoods. It has an open, coarse grain. The color is creamy white. Used for veneer core and moldings. | H |
| Beech | Strong, heavy, hard. Takes a good polish, works easily. The color is white to brown. Also used for tool handles, furniture, and plywood. | H |
| Birch | Very strong, heavy, and fine-grained. It takes an excellent finish. Can be beautifully hand polished. The sapwood is a soft yellow; the heartwood is brown, sometimes slightly colored with red. Due to the climate, birch has a wide variety of color changes. Used for furniture, cabinets, flooring, and plywood. | H |
| Western red cedar | The thin sapwood layer is a pale yellow. The heartwood varies from a deep dark brown to a very light pink. The wood is light and soft, but lacks strength. It is straight-grained and has high resistance to changes in moisture. After seasoning, it retains its shape and size exceptionally well. Used for shingles, shakes, siding, planking, building logs, and yard lumber. | S |
| Tennessee cedar | This product is very light, soft, and close-grained. The sapwood is white in color. The heartwood is reddish brown. This cedar has a very strong odor that acts as an insect repellent. Used for trunk linings and closets. | S |
| Cherry | Cherry is a close-grained and light wood. It takes a good finish and works easily. The sapwood is an off-white. The heartwood is reddish brown. This product can be used for cabinets, interior trim, and furniture. | H |
| Chestnut | This beautiful, open-grained wood is worked very easily. The sapwood is light brown in color. The heartwood is a dark tan. Can be used for cabinets or plywood and paneling. | H |
| Cypress | Cypress is a very durable, light product, and is very easily worked. The heartwood is a briliant yellow; the sapwood is light brown in color. It is used for interior trim and can also be used for cabinet work and exterior trim. | S |
| Elm | This strong, majestic tree is very hard and the lumber is very heavy. The color of this tree is light to medium brown, with slight variations of red and gray. Used primarily for tool handles and heavy construction purposes. | H |
| Douglas fir | Fir is very strong and durable. The sapwood is slightly off-white and the heartwood varies in color from a light red to a deep yellow. Fir is used for all types of construction and in the manufacturing of plywood. | S |
| Western hemlock | This lumber is straight-grained and fine-textured, and it works easily. It has very good qualities for gluing. It is almost totally free from pitch and is often interchanged with fir. Hemlock is used for general construction. | S |
| Gum | This soft-textured, close-grained tree is very durable. The color of the heartwood varies from red to brown. The sapwood is yellowish white. It closely resembles walnut in color. This wood works easily, but has a tendency to warp. It is sometimes substituted for walnut in the manufacture of furniture. | H |
| Larch | This product is strong, fairly hard, and resembles Douglas fir more than any other softwood. This lumber is also suitable for general construction purposes. | H |
| Mahogany | This lumber is an open-pored, strong, durable product. Mahogany can be worked easily. The color is basically a reddish brown. Poor-grade mahogany has small gray spots or flecks. Much mahogany is from overseas. Can be used for paneling, furniture, plywood, and interior trim. | H |
| Sugar maple | This lumber is very difficult to work with, but it is very strong and can take an excellent finish. The product is very close-grained and light brown to dark brown in color. Furniture and flooring are some of its uses. | H |

| Tree | Use | Class (H—Hard, S—Soft) |
|---|---|---|
| Silver maple | This lumber is not very strong or durable. It is soft and light, and it works easily. This lumber is frequently used for turning and interior trim. | H |
| White oak | White oak is very hard and heavy. It has a close grain with open pores. The product is very difficult to work with, but it takes an excellent finish. The heartwood is tan in color, with a light sapwood. Can be used for flooring, plywood, interior trim, and furniture. | H |
| Red oak | Red oak has a coarser grain than white oak and is also a little softer. The variation in color is from a light tan to a medium brown. The uses for red oak are furniture, plywood, bearing posts, interior trim, and paneling. It could also be used for cabinets. | H |
| White pine | This lumber is very easily worked. It is soft, light, and very durable. The heartwood is a very slightly yellowish white. Can be used for construction (code permitting) and is also used in furniture and millwork. | S |
| Sugar pine | This is a light and very soft lumber. It is uniform in texture and works easily. The sapwood is yellow. The heartwood is light red to medium brown. Sugar pine is mostly quarter-sawn and has specks of reddish brown, which makes it easy to recognize. Can be used for inexpensive furniture and interior millwork. | S |
| Ponderosa pine | This pine is fairly soft and uniform in texture. Besides being strong, it works smoothly without splintering. The sapwood is a light pale yellow with a darker heartwood. Ponderosa pine is ideal for woodworking in the shop and is common in door and window frames and moldings. | S |
| Lodgepole pine | This pine lumber seasons very easily and is of moderate durability. This product is soft and straight-grained with a fine, uniform texture. The sapwood is almost white. This product is used largely in making propping timbers for miners. | S |
| Southern yellow pine | This lumber is also called southern pine or yellow pine. It is a very difficult product to work with. It is strong, hard, and tough. The heartwood is orange-red in color, with the sapwood being lighter in color. This product is used for heavy structural purposes such as floor planks, beams, and timbers. | S |
| Poplar | This product is uniform in texture, light, and soft. The color varies from white to yellow. This lumber is easy to work with. Can be used for inexpensive furniture, crates, plywood, and moldings. | H |
| Redwood | The redwood is the largest tree in North America. Redwood is easily worked, light, and coarse-grained. The color is dull red. Although very beautiful, redwood lacks strength. It is used primarily for interior and exterior trim, planking for patio decks, and shingles. | S |
| White spruce | This lumber is soft, works very easily, and is very lightweight. There is very little contrast betwen the heartwood and sapwood. The color is a pale yellow. It is not very durable, but among the softwoods it is one of medium strength. In certain situations, it is vulnerable to decay. White spruce has value as pulp wood and is used in light construction. | S |
| Engelmann spruce | This type of spruce takes a good finish. The lumber is very light and straight-grained. This species is usually larger than white spruce and has a larger percentage of clear lumber with little or no defects. It is used for oars, paddles, sounding boards for musical instruments, and construction work. | S |
| Sitka spruce | These trees have a straight grain and grow very tall. This species is a very tough, strong wood. The color is a very creamy white with a pinkish or light red tinge. This species resists shattering and splintering. It is used primarily in constructing masts, spars, scaffolding, and general construction (code permitting). | S |
| Walnut | This product is durable, very hard, strong and it can easily be finished to a beautiful luster. The sapwood is a light brown to a medium brown. The heartwood is a reddish brown to a dark brown. This product is used in the manufacture of fine cabinets, furniture, flooring, plywood, and interior trim. | H |

# APPENDIX C Lumber Conversion Tables

### Nominal and Actual Softwood Lumber Sizes

| Nominal | Actual (in Inches) | Actual (in Millimeters) |
|---|---|---|
| 1 x 2 | ¾ x 1-½ | 19 x 38 |
| 1 x 4 | ¾ x 3-½ | 19 x 89 |
| 1 x 6 | ¾ x 5-½ | 19 x 140 |
| 1 x 8 | ¾ x 7-¼ | 19 x 184 |
| 1 x 10 | ¾ x 9-¼ | 19 x 235 |
| 1 x 12 | ¾ x 11-¼ | 19 x 286 |
| 5/4 x 4 | 1 x 3-½ | 25 x 89 |
| 5/4 x 6 | 1 x 5-½ | 25 x 140 |
| 2 x 2 | 1-½ x 1-½ | 38 x 38 |
| 2 x 4 | 1-½ x 3-½ | 38 x 89 |
| 2 x 6 | 1-½ x 5-½ | 38 x 140 |
| 2 x 8 | 1-½ x 7-¼ | 38 x 184 |
| 2 x 10 | 1-½ x 9-¼ | 38 x 235 |
| 2 x 12 | 1-½ x 11-¼ | 38 x 286 |
| 4 x 4 | 3-½ x 3-½ | 89 x 89 |
| 4 x 6 | 3-½ x 5-½ | 89 x 140 |
| 6 x 6 | 5-½ x 5-½ | 140 x 140 |
| 6 x 8 | 5-½ x 7-½ | 140 x 190 |
| 8 x 8 | 7-½ x 7-½ | 190 x 190 |

### Nominal and Actual Hardwood Lumber Sizes

| Nominal (Rough) | Actual (Plain) | Actual (S4S) |
|---|---|---|
| ½" | 5/16" | 5/16" |
| ⅝" | 7/16" | 7/16" |
| ¾" | 9/16" | 9/16" |
| 1" | 25/32" | 25/32" |
| 1¼" | 1 1/16" | 1 1/32" |
| 1½" | 1 5/16" | 1 9/32" |
| 2" | 1¾" | 1 11/16" |
| 2½" | 2¼" | 2¼" |
| 3" | 2¾" | 2¾" |
| 4" | 3¾" | 3¾" |

### Rapid Calculation of Board Measure

| Width | Thickness | Board Feet |
|---|---|---|
| 3" | 1" or less | ¼ of the length |
| 4" | 1" or less | ⅓ of the length |
| 6" | 1" or less | ½ of the length |
| 9" | 1" or less | ¾ of the length |
| 12" | 1" or less | Same as the length |
| 15" | 1" or less | 1¼ of the length |

**Board Feet**

| Nominal Size (in Inches) | Actual Length (in Feet) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 8 | 10 | 12 | 14 | 16 | 18 | 20 | 22 | 24 |
| 1 x 2 | | 1⅔ | 2 | 2⅓ | 2⅔ | 3 | 3½ | 3⅔ | 4 |
| 1 x 3 | | 2½ | 3 | 3½ | 4 | 4½ | 5 | 5½ | 6 |
| 1 x 4 | 2¾ | 3⅓ | 4 | 4⅔ | 5⅓ | 6 | 6⅔ | 7⅓ | 8 |
| 1 x 5 | | 4⅙ | 5 | 5⅚ | 6⅔ | 7½ | 8⅓ | 9⅙ | 10 |
| 1 x 6 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| 1 x 7 | | 5⅝ | 7 | 8⅙ | 9⅓ | 10½ | 11⅔ | 12⅚ | 14 |
| 1 x 8 | 5⅓ | 6⅔ | 8 | 9⅓ | 10⅔ | 12 | 13⅓ | 14⅔ | 16 |
| 1 x 10 | 6⅔ | 8⅓ | 10 | 11⅔ | 13⅓ | 15 | 16⅔ | 18⅓ | 20 |
| 1 x 12 | 8 | 10 | 12 | 14 | 16 | 18 | 20 | 22 | 24 |
| 1¼ x 4 | | 4⅙ | 5 | 5⅚ | 6⅔ | 7½ | 8⅓ | 9⅙ | 10 |
| 1¼ x 6 | | 6¼ | 7½ | 8¾ | 10 | 11¼ | 12½ | 13¾ | 15 |
| 1¼ x 8 | | 8⅓ | 10 | 11⅔ | 13⅓ | 15 | 16⅔ | 18⅓ | 20 |
| 1¼ x 10 | | 10⁵⁄₁₂ | 12½ | 14⁷⁄₁₂ | 16⅔ | 18¾ | 20⅚ | 22¹¹⁄₁₂ | 25 |
| 1¼ x 12 | | 12½ | 15 | 17½ | 20 | 22½ | 25 | 27½ | 30 |
| 1½ x 4 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| 1½ x 6 | 6 | 7½ | 9 | 10½ | 12 | 13½ | 15 | 16½ | 18 |
| 1½ x 8 | 8 | 10 | 12 | 14 | 16 | 18 | 20 | 22 | 24 |
| 1½ x 10 | 10 | 12½ | 15 | 17½ | 20 | 22½ | 25 | 27½ | 30 |
| 1½ x 12 | 12 | 15 | 18 | 21 | 24 | 27 | 30 | 33 | 36 |
| 2 x 4 | 5⅓ | 6⅔ | 8 | 9⅓ | 10⅓ | 12 | 13⅓ | 14⅔ | 16 |
| 2 x 6 | 8 | 10 | 12 | 14 | 16 | 18 | 20 | 22 | 24 |
| 2 x 8 | 10⅔ | 13⅓ | 16 | 18⅔ | 21⅓ | 24 | 26⅔ | 29⅓ | 32 |
| 2 x 10 | 13⅓ | 16⅔ | 20 | 23⅓ | 26⅔ | 30 | 33⅓ | 36⅔ | 40 |
| 2 x 12 | 16 | 20 | 24 | 28 | 32 | 36 | 40 | 44 | 48 |
| 3 x 6 | 12 | 15 | 18 | 21 | 24 | 27 | 30 | 33 | 36 |
| 3 x 8 | 16 | 20 | 24 | 28 | 32 | 36 | 40 | 44 | 48 |
| 3 x 10 | 20 | 25 | 30 | 35 | 40 | 45 | 50 | 55 | 60 |
| 3 x 12 | 24 | 30 | 36 | 42 | 48 | 54 | 60 | 66 | 72 |
| 4 x 4 | 10⅔ | 13⅓ | 16 | 18⅔ | 21⅓ | 24 | 26⅔ | 29⅓ | 32 |
| 4 x 6 | 16 | 20 | 24 | 28 | 32 | 36 | 40 | 44 | 48 |
| 4 x 8 | 21⅓ | 26⅔ | 32 | 37⅓ | 42⅔ | 48 | 53⅓ | 58⅔ | 64 |
| 4 x 10 | 26⅔ | 33⅓ | 40 | 46⅔ | 53⅓ | 60 | 66⅔ | 73⅓ | 80 |
| 4 x 12 | 32 | 40 | 48 | 56 | 64 | 72 | 80 | 88 | 96 |

# APPENDIX D Common Abbreviations Used in the Lumber Industry

| | |
|---|---|
| AD | Air Dried |
| ADF | After Deducting Freight |
| ALS | American Lumber Standard |
| AST | Anti-Stain Treated |
| AVG | Average |
| B & B | B and Better |
| B & S | Beams and Stringers |
| Bd. | Board |
| BF or Bd. Ft. | Board Feet |
| Bdl. | Bundle or Bundled |
| B/L | Bill of Lading |
| Bev. | Bevel or Beveled |
| CB1S | Center Bead on One Side |
| CB2S | Center Bead on Two Sides |
| CC | Cubical Content |
| Cft. or Cu. Ft. | Cubic Feet or Foot |
| CG2E | Center Groove on Two Edges |
| CIF | Cost, Insurance, and Freight |
| CIFE | Cost, Insurance, Freight, and Exchange |
| Clg. | Ceiling |
| Com. | Common |
| Csg. | Casing |
| Ctr. | Center |
| CV1S | Center V on One Side |
| CV2S | Center V on Two Sides |
| D & M | Dressed and Matched |
| DB Clg. | Double-Beaded Ceiling |
| DB Part | Double-Beaded Partition |
| DET | Double-End-Trimmed |
| Dim. | Dimension |
| Dkg. | Decking |
| D/sdg | Drop Siding |
| EB1S | Edge Bead on One Side |
| EB2S | Edge Bead on Two Sides |
| EE | Eased Edges |
| EG | Edge Vertical or Rift Grain |
| EM | End Matched |
| EV1S | Edge V on One Side |
| EV2S | Edge V on Two Sides |
| E & CB1S | Edge and Center Bead on One Side |
| Part. | Partition |
| Pat. | Pattern |
| Pcs. | Pieces |
| PE | Plain End |
| P & T | Post and Timbers |
| P1S and P2S | See S1S and S2S |
| Reg. | Regular |
| Rfg. | Roofing |
| Rgh. | Rough |
| E & CB2S | Edge and Center Bead on Two Sides |
| E & CV1S | Edge and Center V on One Side |
| E & CV2S | Edge and Center V on Two Sides |
| FA | FacialArea |
| Fac. | Factory |
| FBM | Feet Board Measure |
| FG | Flat (slash) Grain |
| Flg. | Flooring |
| FOB | Free on Board |
| FOHC | Free of Heart Centers |
| FOK | Free of Knots |
| Frt. | Freight |
| Ft. | Foot or Feet |
| G | Girth |
| GM | Grade Marked |
| G/R | Grooved Roofing |
| HB | Hollow Back |
| Hrt. | Heart |
| H & M | Hit and Miss |
| in. | Inch or Inches |
| Ind. | Industrial |
| J & P | Joints and Planks |
| KD | Kiln Dried |
| Lbr. | Lumber |
| LCL | Less than Carload |
| Lft. | Lineal Foot or Feet |
| Lin. | Lineal |
| LL | Longleaf |
| Lng. | Lining |
| M | Thousand |
| MBM | Thousand (feet) Board Measure |
| M.C. | Moisture Content |
| Merch. | Merchantable |
| MG | Medium Grain |
| MLDG. | Molding |
| Mft. | Thousand Feet |
| No. | Number |
| N1E or N2E | Nosed on One or Two Edges |
| Ord. | Order |
| Par. | Paragraph |
| STR | Structural |
| SYP | Southern Yellow Pine |
| S & E | Side and Edge (surfaced on) |
| S1E | Surfaced on One Edge |
| S2E | Surfaced on Two Edges |
| S1S | Surfaced on One Side |
| S2S | Surfaced on Two Sides |
| S1S1E | Surfaced on One Side and One Edge |

| | |
|---|---|
| R/L | Random Length |
| RES | Resawn |
| Sdg. | Siding |
| S E | Square Edge |
| Sel. | Select |
| S E & S | Square Edge and Sound |
| SL | Shiplap |
| SM | Surface Measure |
| Specs. | Specifications |
| SR | Stress Rated |
| Std. | Standard |
| Std. Lgths. | Standard Lengths |
| STDM | Standard Matched |
| SSND | Sap Stained No Defects (stained) |
| S2S2E | Surfaced on Two Sides and Two Edges |
| S2S1E | Surfaced on Two Sides and One Edge |
| S2S & CM | Surfaced on Two Sides and Center Matched |
| S2S - SL | Surfaced on Two Sides and Shiplapped |
| S2S & SM | Surfaced on Two Sides and Standard Matched |
| S4S | Surfaced on Four Sides |
| T & G | Tongued and Grooved |
| Wdr. | Wider |
| Wt. | Weight |
| YP | Yellow Pine |

# APPENDIX E Formulas for Geometric Shapes and Conversion Tables

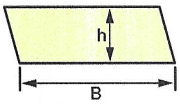
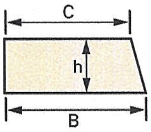
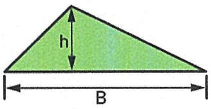
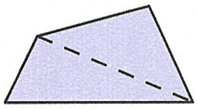
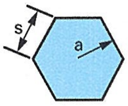
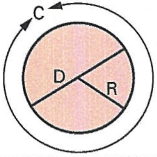
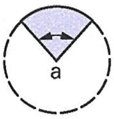
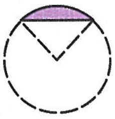
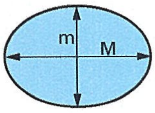
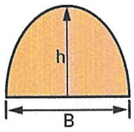
**Conversion Table for Changing Measurements (in Inches) to Fractions and Decimal Parts of a Foot**

| Inches | Fractional Part of Foot | Decimal Part of Foot |
|---|---|---|
| 1 | 1/12 | 0.08 |
| 2 | 1/16 | 0.17 |
| 3 | 1/4 | 0.25 |
| 4 | 1/3 | 0.33 |
| 5 | 5/12 | 0.42 |
| 6 | 1/2 | 0.50 |
| 7 | 7/12 | 0.58 |
| 8 | 2/3 | 0.67 |
| 9 | 3/4 | 0.75 |
| 10 | 5/6 | 0.83 |
| 11 | 11/12 | 0.92 |
| 12 | 1 | 1.00 |

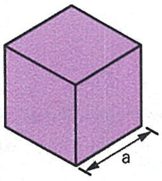
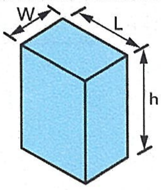
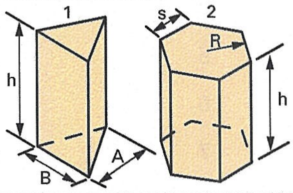
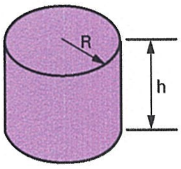
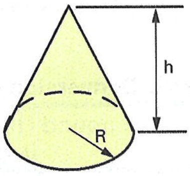
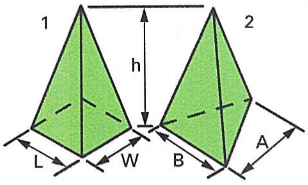
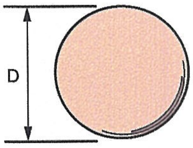
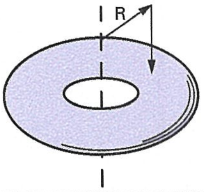
**Metric Conversion of Pounds to Grams or Kilograms**

1 pound (16 ounces) = 453.6 grams or 0.4536 kilogram (kg)

## AREAS OF PLANE FIGURES

| NAME FORMULA | SHAPE |
|---|---|
| (A = Area)<br>Parallelogram<br>$A = B \times h$ |  |
| Trapezoid<br>$A = \frac{B + C}{2} \times h$ |  |
| Triangle<br>$A = \frac{B \times h}{2}$ |  |
| Trapezium<br>(Divide into 2 triangles)<br>A = Sum of the 2 triangles<br>(See above) |  |
| Regular Polygon<br>$A = \frac{aP}{2}$<br>Where<br>a is the length of the *apothem* (perpendicular distance from center to a side)<br>P is the *perimeter* (sum of the sides, s) |  |
| Circle<br>$\pi = 3.14$<br>$(1)\ \pi R^2$<br>$A = (2)\ .7854 \times D^2$ |  |
| Sector<br>$(1) \frac{a^\circ}{360^\circ} \times \pi R^2$<br>$A = (2)$ Length of arc $\times \frac{R}{2}$<br>($\pi = 3.14$, a = angle of sector) |  |
| Segment<br>A = Area of sector minus triangle (see above) |  |
| Ellipse<br>$A = M \times m \times .7854$ |  |
| Parabola<br>$A = B \times \frac{2h}{3}$ |  |

## VOLUMES OF SOLID FIGURES

| NAME FORMULA | SHAPE |
|---|---|
| (V – volume)<br>Cube<br>$V = a^3$ (in cubic units) |  |
| Rectangular Solids<br>$V = L \times W \times h$ |  |
| Prisms<br>$V(1) = \frac{B \times A}{2} \times h$<br>$V(2) = \frac{s \times R}{2} \times n \times h$<br>V = Area of end x h<br>n = Number of sides |  |
| Cylinder<br>$V = \pi R^2 \times h$<br>$(\pi = 3.14)$ |  |
| Cone<br>$V = \frac{\pi R^2 \times h}{3}$<br>$(\pi = 3.14)$ |  |
| Pyramids<br>$V(1) = L \times W \times \frac{h}{3}$<br>$V(2) = \frac{B \times A}{2} \times \frac{h}{3}$<br>V = Area of Base $\times \frac{h}{3}$ |  |
| Sphere<br>$V(1) = \frac{1}{6} \pi D^3$<br>$V(2) = \frac{4}{3} \pi R^3$ |  |
| Circular Ring (Torus)<br>$V = 2\pi^2 \times Rr^2$<br>V = Area of section $\times 2\pi R$<br>R = radius of the ring at its center, i.e., (OD – ID)/2 + ½ID; r = radius of the cross section of the ring at R. |  |

## METRIC CONVERSION CHART

| inches | | m m |
|---|---|---|
| fractions | decimals | |
| — | .0004 | .01 |
| — | .004 | .10 |
| — | .01 | .25 |
| 1/64 | .0156 | .397 |
| — | .0197 | .50 |
| — | .0295 | .75 |
| 1/32 | .03125 | .794 |
| — | .0394 | 1. |
| 3/64 | .0469 | 1.191 |
| — | .059 | 1.5 |
| 1/16 | .062 | 1.588 |
| 5/64 | .0781 | 1.984 |
| — | .0787 | 2. |
| 3/32 | .094 | 2.381 |
| — | .0984 | 2.5 |
| 7/64 | .109 | 2.778 |
| — | .1181 | 3. |
| 1/8 | .125 | 3.175 |
| — | .1378 | 3.5 |
| 9/64 | .141 | 3.572 |
| 5/32 | .156 | 3.969 |
| — | .1575 | 4. |
| 11/64 | .172 | 4.366 |
| — | .177 | 4.5 |
| 3/16 | .1875 | 4.763 |
| — | .1969 | 5. |
| 13/64 | .203 | 5.159 |
| — | .2165 | 5.5 |
| 7/32 | .219 | 5.556 |
| 15/64 | .234 | 5.953 |
| — | .2362 | 6. |
| 1/4 | .250 | 6.350 |
| — | .2559 | 6.5 |
| 17/64 | .2656 | 6.747 |
| — | .2756 | 7. |
| 9/32 | .281 | 7.144 |
| — | .2953 | 7.5 |
| 19/64 | .297 | 7.541 |
| 5/16 | .312 | 7.938 |
| — | .315 | 8. |
| 21/64 | .328 | 8.334 |
| — | .335 | 8.5 |
| 11/32 | .344 | 8.731 |
| — | .3543 | 9. |
| 23/64 | .359 | 9.128 |
| — | .374 | 9.5 |
| 3/8 | .375 | 9.525 |
| 25/64 | .391 | 9.922 |
| — | .3937 | 10. |
| 13/32 | .406 | 10.319 |
| — | .413 | 10.5 |
| 27/64 | .422 | 10.716 |
| — | .4331 | 11. |
| 7/16 | .438 | 11.113 |
| 29/64 | .453 | 11.509 |
| 15/32 | .469 | 11.906 |
| — | .4724 | 12. |
| 31/64 | .484 | 12.303 |
| — | .492 | 12.5 |
| 1/2 | .500 | 12.700 |
| — | .5118 | 13. |
| 33/64 | .5156 | 13.097 |
| 17/32 | .531 | 13.494 |
| 35/64 | .547 | 13.891 |
| — | .5512 | 14. |
| 9/16 | .563 | 14.288 |
| — | .571 | 14.5 |
| 37/64 | .578 | 14.684 |
| — | .5906 | 15. |
| 19/32 | .594 | 15.081 |
| 39/64 | .609 | 15.478 |
| 5/8 | .625 | 15.875 |
| — | .6299 | 16. |
| 41/64 | .6406 | 16.272 |
| — | .6496 | 16.5 |
| 21/32 | .656 | 16.669 |
| — | .6693 | 17. |
| 43/64 | .672 | 17.066 |
| 11/16 | .6875 | 17.463 |
| 45/64 | .703 | 17.859 |
| — | .7087 | 18. |
| 23/32 | .719 | 18.256 |
| — | .7283 | 18.5 |
| 47/64 | .734 | 18.653 |
| — | .7480 | 19. |
| 3/4 | .750 | 19.050 |
| 49/64 | .7656 | 19.447 |
| 25/32 | .781 | 19.844 |
| — | .7874 | 20. |
| 51/64 | .797 | 20.241 |
| 13/16 | .8125 | 20.638 |
| — | .8268 | 21. |
| 53/64 | .828 | 21.034 |
| 27/32 | .844 | 21.431 |
| 55/64 | .859 | 21.828 |
| — | .8661 | 22. |
| 7/8 | .875 | 22.225 |
| 57/64 | .8906 | 22.622 |
| — | .9055 | 23. |
| 29/32 | .9062 | 23.019 |
| 59/64 | .922 | 23.416 |
| 15/16 | .9375 | 23.813 |
| — | .9449 | 24. |
| 61/64 | .953 | 24.209 |
| 31/32 | .969 | 24.606 |
| — | .9843 | 25. |
| 63/64 | .9844 | 25.003 |
| 1 | 1.000 | 25.400 |
| — | 1.0236 | 26. |
| 1-1/32 | 1.0312 | 26.194 |
| 1-1/16 | 1.062 | 26.988 |
| — | 1.063 | 27. |
| 1-3/32 | 1.094 | 27.781 |
| — | 1.1024 | 28. |
| 1-1/8 | 1.125 | 28.575 |
| — | 1.1417 | 29. |
| 1-5/32 | 1.156 | 29.369 |
| — | 1.1811 | 30. |
| 1-3/16 | 1.1875 | 30.163 |
| 1-7/32 | 1.219 | 30.956 |
| — | 1.2205 | 31. |
| 1-1/4 | 1.250 | 31.750 |
| — | 1.2598 | 32. |
| 1-9/32 | 1.281 | 32.544 |
| — | 1.2992 | 33. |
| 1-5/16 | 1.312 | 33.338 |
| — | 1.3386 | 34. |
| 1-11/32 | 1.344 | 34.131 |
| 1-3/8 | 1.375 | 34.925 |
| — | 1.3779 | 35. |
| 1-13/32 | 1.406 | 35.719 |
| — | 1.4173 | 36. |
| 1-7/16 | 1.438 | 36.513 |
| — | 1.4567 | 37. |
| 1-15/32 | 1.469 | 37.306 |
| — | 1.4961 | 38. |
| 1-1/2 | 1.500 | 38.100 |
| 1-17/32 | 1.531 | 38.894 |
| — | 1.5354 | 39. |
| 1-9/16 | 1.562 | 39.688 |
| — | 1.5748 | 40. |
| 1-19/32 | 1.594 | 40.481 |
| — | 1.6142 | 41. |
| 1-5/8 | 1.625 | 41.275 |
| — | 1.6535 | 42. |
| 1-21/32 | 1.6562 | 42.069 |
| 1-11/16 | 1.6875 | 42.863 |
| — | 1.6929 | 43. |
| 1-23/32 | 1.719 | 43.656 |
| — | 1.7323 | 44. |
| 1-3/4 | 1.750 | 44.450 |
| — | 1.7717 | 45. |
| 1-25/32 | 1.781 | 45.244 |
| — | 1.8110 | 46. |
| 1-13/16 | 1.8125 | 46.038 |
| 1-27/32 | 1.844 | 46.831 |
| — | 1.8504 | 47. |
| 1-7/8 | 1.875 | 47.625 |
| — | 1.8898 | 48. |
| 1-29/32 | 1.9062 | 48.419 |
| — | 1.9291 | 49. |
| 1-15/16 | 1.9375 | 49.213 |
| — | 1.9685 | 50. |
| 1-31/32 | 1.969 | 50.006 |
| 2 | 2.000 | 50.800 |
| — | 2.0079 | 51. |
| 2-1/32 | 2.03125 | 51.594 |
| — | 2.0472 | 52. |
| 2-1/16 | 2.062 | 52.388 |
| — | 2.0866 | 53. |
| 2-3/32 | 2.094 | 53.181 |
| 2-1/8 | 2.125 | 53.975 |
| — | 2.126 | 54. |
| 2-5/32 | 2.156 | 54.769 |
| — | 2.165 | 55. |
| 2-3/16 | 2.1875 | 55.563 |
| — | 2.2047 | 56. |
| 2-7/32 | 2.219 | 56.356 |
| — | 2.244 | 57. |
| 2-1/4 | 2.250 | 57.150 |
| 2-9/32 | 2.281 | 57.944 |
| — | 2.2835 | 58. |
| 2-5/16 | 2.312 | 58.738 |
| — | 2.3228 | 59. |
| 2-11/32 | 2.344 | 59.531 |
| — | 2.3622 | 60. |
| 2-3/8 | 2.375 | 60.325 |
| — | 2.4016 | 61. |
| 2-13/32 | 2.406 | 61.119 |
| 2-7/16 | 2.438 | 61.913 |
| — | 2.4409 | 62. |
| 2-15/32 | 2.469 | 62.706 |
| — | 2.4803 | 63. |
| 2-1/2 | 2.500 | 63.500 |
| — | 2.5197 | 64. |
| 2-17/32 | 2.531 | 64.294 |
| — | 2.559 | 65. |
| 2-9/16 | 2.562 | 65.088 |
| 2-19/32 | 2.594 | 65.881 |
| — | 2.5984 | 66. |
| 2-5/8 | 2.625 | 66.675 |
| — | 2.638 | 67. |
| 2-21/32 | 2.656 | 67.469 |
| — | 2.6772 | 68. |
| 2-11/16 | 2.6875 | 68.263 |
| — | 2.7165 | 69. |
| 2-23/32 | 2.719 | 69.056 |
| 2-3/4 | 2.750 | 69.850 |
| — | 2.7559 | 70. |
| 2-25/32 | 2.781 | 70.6439 |
| — | 2.7953 | 71. |
| 2-13/16 | 2.8125 | 71.4376 |
| — | 2.8346 | 72. |
| 2-27/32 | 2.844 | 72.2314 |
| — | 2.8740 | 73. |
| 2-7/8 | 2.875 | 73.025 |
| 2-29/32 | 2.9062 | 73.819 |
| — | 2.9134 | 74. |
| 2-15/16 | 2.9375 | 74.613 |
| — | 2.9527 | 75. |
| 2-31/32 | 2.969 | 75.406 |
| — | 2.9921 | 76. |
| 3 | 3.000 | 76.200 |
| 3-1/32 | 3.0312 | 76.994 |
| — | 3.0315 | 77. |
| 3-1/16 | 3.062 | 77.788 |
| — | 3.0709 | 78. |
| 3-3/32 | 3.094 | 78.581 |
| — | 3.1102 | 79. |
| 3-1/8 | 3.125 | 79.375 |
| — | 3.1496 | 80. |
| 3-5/32 | 3.156 | 80.169 |
| 3-3/16 | 3.1875 | 80.963 |
| — | 3.1890 | 81. |
| 3-7/32 | 3.219 | 81.756 |
| — | 3.2283 | 82. |
| 3-1/4 | 3.250 | 82.550 |
| — | 3.2677 | 83. |
| 3-9/32 | 3.281 | 83.344 |
| — | 3.3071 | 84. |
| 3-5/16 | 3.312 | 84.1377 |
| 3-11/32 | 3.344 | 84.9314 |
| — | 3.3464 | 85. |
| 3-3/8 | 3.375 | 85.725 |
| — | 3.3858 | 86. |
| 3-13/32 | 3.406 | 86.519 |
| — | 3.4252 | 87. |
| 3-7/16 | 3.438 | 87.313 |
| — | 3.4646 | 88. |
| 3-15/32 | 3.469 | 88.106 |
| 3-1/2 | 3.500 | 88.900 |
| — | 3.5039 | 89. |
| 3-17/32 | 3.531 | 89.694 |
| — | 3.5433 | 90. |
| 3-9/16 | 3.562 | 90.4877 |
| — | 3.5827 | 91. |
| 3-19/32 | 3.594 | 91.281 |
| — | 3.622 | 92. |
| 3-5/8 | 3.625 | 92.075 |
| 3-21/32 | 3.656 | 92.869 |
| — | 3.6614 | 93. |
| 3-11/16 | 3.6875 | 93.663 |
| — | 3.7008 | 94. |
| 3-23/32 | 3.719 | 94.456 |
| — | 3.7401 | 95. |
| 3-3/4 | 3.750 | 95.250 |
| — | 3.7795 | 96. |
| 3-25/32 | 3.781 | 96.044 |
| 3-13/16 | 3.8125 | 96.838 |
| — | 3.8189 | 97. |
| 3-27/32 | 3.844 | 97.631 |
| — | 3.8583 | 98. |
| 3-7/8 | 3.875 | 98.425 |
| — | 3.8976 | 99. |
| 3-29/32 | 3.9062 | 99.219 |
| — | 3.9370 | 100. |
| 3-15/16 | 3.9375 | 100.013 |
| 3-31/32 | 3.969 | 100.806 |
| — | 3.9764 | 101. |
| 4 | 4.000 | 101.600 |
| 4-1/16 | 4.062 | 103.188 |
| 4-1/8 | 4.125 | 104.775 |
| — | 4.1338 | 105. |
| 4-3/16 | 4.1875 | 106.363 |
| 4-1/4 | 4.250 | 107.950 |
| 4-5/16 | 4.312 | 109.538 |
| — | 4.3307 | 110. |
| 4-3/8 | 4.375 | 111.125 |
| 4-7/16 | 4.438 | 112.713 |
| 4-1/2 | 4.500 | 114.300 |
| — | 4.5275 | 115. |
| 4-9/16 | 4.562 | 115.888 |
| 4-5/8 | 4.625 | 117.475 |
| 4-11/16 | 4.6875 | 119.063 |
| — | 4.7244 | 120. |
| 4-3/4 | 4.750 | 120.650 |
| 4-13/16 | 4.8125 | 122.238 |
| 4-7/8 | 4.875 | 123.825 |
| — | 4.9212 | 125. |
| 4-15/16 | 4.9375 | 125.413 |
| 5 | 5.000 | 127.000 |
| — | 5.1181 | 130. |
| 5-1/4 | 5.250 | 133.350 |
| 5-1/2 | 5.500 | 139.700 |
| — | 5.5118 | 140. |
| 5-3/4 | 5.750 | 146.050 |
| — | 5.9055 | 150. |
| 6 | 6.000 | 152.400 |
| 6-1/4 | 6.250 | 158.750 |
| — | 6.2992 | 160. |
| 6-1/2 | 6.500 | 165.100 |
| — | 6.6929 | 170. |
| 6-3/4 | 6.750 | 171.450 |
| 7 | 7.000 | 177.800 |
| — | 7.0866 | 180. |
| — | 7.4803 | 190. |
| 7-1/2 | 7.500 | 190.500 |
| — | 7.8740 | 200. |
| 8 | 8.000 | 203.200 |
| — | 8.2677 | 210. |
| 8-1/2 | 8.500 | 215.900 |
| — | 8.6614 | 220. |
| 9 | 9.000 | 228.600 |
| — | 9.0551 | 230. |
| — | 9.4488 | 240. |
| 9-1/2 | 9.500 | 241.300 |
| — | 9.8425 | 250. |
| 10 | 10.000 | 254.001 |
| — | 10.2362 | 260. |
| — | 10.6299 | 270. |
| 11 | 11.000 | 279.401 |
| — | 11.0236 | 280. |
| — | 11.4173 | 290. |
| — | 11.8110 | 300. |
| 12 | 12.000 | 304.801 |
| 13 | 13.000 | 330.201 |
| — | 13.7795 | 350. |
| 14 | 14.000 | 355.601 |
| 15 | 15.000 | 381.001 |
| — | 15.7480 | 400. |
| 16 | 16.000 | 406.401 |
| 17 | 17.000 | 431.801 |
| — | 17.7165 | 450. |
| 18 | 18.000 | 457.201 |
| 19 | 19.000 | 482.601 |
| — | 19.6850 | 500. |
| 20 | 20.000 | 508.001 |

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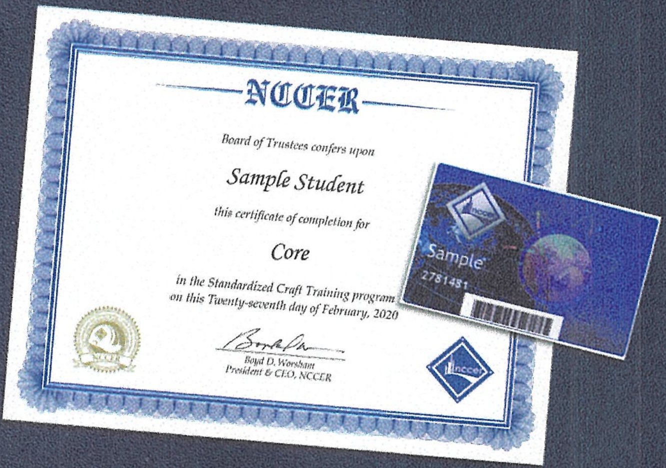

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